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BY

WILLIAM PIERSON JUDSON, M. Am. Soc. C. E.

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ROAD PRESERVATION

AND

DUST PREVENTION

BY

WILLIAM PIERSON JUDSON

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Member of the American Society of Civil Engineers
Member of the Institution of Civil Engineers (of Great Britain)
Member of the Massachusetts Highway Association
Member of the American Society of Municipal Improvements
Author of "City Roads and Pavements"

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PREFACE.

THE preservation of surface and the prevention of dust on macadamized roads form the problem now to be solved by engineers charged with the maintenance of the many thousands of miles of broken-stone roads which have been built throughout Europe during the past century, and in certain of the United States during the past decade.

During 1906, with the increased use of motor-cars, this problem became acute, and in 1908 it is conceded to be a matter of prompt betterment, or general destruction, of costly highways.

This implies that new roads proposed and in progress must be better built than the old ones; that they must be better bonded and surfaced; and that these results must be reached, if possible, without unduly increasing the cost.

Preservation of existing roads and dust prevention on them are the matters which are most urgent, and road-builders have been working and experimenting to these ends with results which are here shown; including the observations and conclusions of the writer who is indebted for many of the details to the engineers of the works named, as well as to the engineering publications of the United States and of Europe, among which are: the *Engi-*

neering News, the *Engineering Record*, the *Good Roads Magazine*, the *Municipal Journal and Engineer*, and the *American Gas-light Journal*, all of New York; *Municipal Engineering* of Indianapolis; *Engineering-Contracting* of Chicago; *The Engineer*, the *Surveyor and Municipal and County Engineer*, and the *Journal of Gas-lighting* of London; *The Journal Fuer Gasbeleuchtung* of Berlin; the publications and records of the U. S. Office of Public Roads, at Washington; the reports of the State Highway Departments of New York, Massachusetts, New Jersey, Connecticut, and Rhode Island; the report of the Chief of the U. S. Corps of Engineers; the *Annals des Ponts et Chausses* of France; and especially the Minutes of the Institution of Civil Engineers of Great Britain; the Proceedings of the American Society of Civil Engineers; the Journal of the Massachusetts Highway Association (as well as its informal but valuable discussions); and the Proceedings of the American Society of Municipal Improvements. The general estimate of the importance of the subject is indicated by the extent of its discussions in these and many other publications.

WM. P. J.

OSWEGO, New York,
July 1, 1908.

ROAD PRESERVATION AND DUST PREVENTION.

ROAD DUST: ITS CONTROL AND PREVENTION.

Dust has always been a feature of broken-stone roads, being at the same time the result of use and a check upon excessive wear. Whenever the surface becomes free from dust, by wind effect or otherwise, it has been necessary to spread a thin layer of sand or screenings, or other fine material, as a protection to the stone-fragments forming the road, and to prevent them from "ravelling" or losing their bond. When these stones or the screenings forming the protective layer, or both, have consisted of limestone, the resulting impalpable dust has always been most objectionable and in many cases has been considered intolerable, both to people driving upon the road and especially to those living along it. When this limestone dust is wet, the resulting mud is the most slippery and dangerous for rubber-tired wheels, causing more side-slip than any other material used for roads.

MOTOR-CAR EFFECTS.

In 1905, when motor-cars became common, the raising and scattering of road-dust increased greatly, and in the summer of 1906 when motor-cars became very numerous both in Europe and in the United States, the subject at once became acute, and road-builders everywhere found that a new condition had suddenly developed (particularly on those macadam roads radiating from the cities where motor-cars were most used), and that the preservation of the roads demanded that a better and more enduring surface be made, and one that will neither require nor produce the loose surface layer which has heretofore been a necessary feature.

In England.—In the Minutes of Proceedings of the Institution of Civil Engineers (of Great Britain) for September, 1906, it is said:

"Experience has proved that the broad pneumatic tires of heavy motor-cars at high speed draw out small particles which bind the material of a macadamized road. On the main roads (of England) more than half the traffic is of motor-cars, which may reasonably be expected to become a more and more popular means of travel, to which the roads must now be adapted by introducing into them some material which would make them dustless; for which purpose, tar, or some tar derivative, is the only remedy now in sight. Motors have come to stay, and the road-builders mean to make the roads fit to carry them. The estimated cost of this on the main rural roads of England and Wales is put at eighty million pounds and of the district roads outside the main roads at 184 million pounds. (A total of one and one-third billion dollars.)

In the United States.—That this condition equally concerns the road-builders of the United States is shown in

the 1907 report of Logan W. Page, Director of the U. S. Office of Public Roads, in which he says:

"In recent years perhaps the most important and certainly the most difficult problem which has engaged the attention of highway engineers is the prevention of dust. Until the general introduction of motor vehicles, dust was considered as neither more nor less than a nuisance. The problem has now, however, assumed a more serious aspect. The existence of our macadam roads depends upon the retention of the road-dust formed by the wearing of the surface. But the action of rubber-tired motor-cars moving at high speed soon strips the macadam road of all fine material, the result being that the road soon disintegrates. . . . This is a subject which should engage the earnest attention of the National Government at once. No matter how important we may deem the building of good roads, we cannot but consider it even more important to preserve those which have already been constructed."

James Owen, M. Am. Soc. C. E., one of the most experienced of American road-engineers, in an able paper on "Highway Construction," before the 1906 meeting of the American Society of Municipal Improvements, said:

"Every system of road construction should be immediately supplemented by a maintenance organization, for in time the construction department disappears, but the maintenance department is permanent, and is the vital point in the future road-development of the country. . . . The automobile is demanding attention from engineers as to whether there should not be new means and methods for road maintenance."

At the annual meeting of the American Road-makers' Association on March, 12, 1907, Wm. E. McClintock, chairman of the Massachusetts Highway Commission, said:

"We have a new problem within the last six months, which is that of the destruction of the stone road by the automobile. The surface is denuded, the fine stone thrown off, and our commission is strug-

gling with the problem in the hope of finding some method to stop the ravelling, and also to prevent the tremendous dust which follows the motor-car."

DANGER FROM DUST.

The London *Lancet* of July, 1907, refers to this road-dust as

"This great modern plague which is a menace to health."

The Paris *Revue Scientifique*, says:

"Street-dust is a menace to health of the gravest character, and is a matter of life and death."

THE DUST NUISANCE

Not only does the demand for relief come from recognized authorities and from the road-users, but also from the property owners who live along the roads, and pay for them, and who find that the

former dust to which they had objected has become an hundred fold worse and not to be endured; especially in England, country residences which have long been desirable and valuable, have suddenly become neither tenable nor saleable, and others have been sold for half their cost because of the dust from adjacent roads. In Massachusetts, passing motor-cars have even thrown up fragments of road-stones into the windows of houses.

CHANGE IN METHODS.

Massachusetts Highway Association.—At the meeting of the Massachusetts Highway Association on November 12, 1907, Col. Wm. D. Sohier, of Boston and Beverly, made the statement that

> "A macadam road, made of crushed stone and bound with rolled screenings and water, has gone out of date";

and this was not questioned by any of the hundred or more other members present.

The situation cannot be better stated than by quoting the 1907 report of the Massachusetts Highway Commission which has built and maintains the main parts of one of the finest road-systems in the United States; the Commission being seconded in every direction by the members of the Massachusetts Highway Association, whose local roads join and extend those of the State; the secretary of the Commission, A. B. Fletcher, being also the secretary of the Association, so that all road-builders in the State profit by each other's experience and operate in friendly rivalry; the Association thus doing for Massachusetts what the American Society of Municipal Im-

provements aims to do for the United States and Canada.

Massachusetts Highway Commission.—The 1907 report states as follows:

"Perhaps the most important discovery of the year is the extraordinarily destructive effects upon stone roads of the large number of swiftly moving automobiles. Practically all the main roads are thus affected. It has been noted that the binder is swept from the road, and that the 'number-two stone' (½ inch to 1½ inch size) is disturbed; in some instances standing on the surface, and in others being left in windrows along the roadside. The Commission is satisfied that a material change in the methods of maintaining stone roads must be made. While old methods have proved satisfactory in the past, they fail under the present usage. The automobile has come to stay, and will increase in numbers, and it must be reckoned with. It must be borne in mind that this excessive wear of stone roads by automobiles is not confined to Massachusetts. Reports show that the same trouble is experienced in all parts of the United States. The roads of England, France, and other countries of Europe are also showing signs of destruction by the same agency."

The 1908 report of the Commission says:

"The destructive work of automobiles during the past year was even more marked than it was in 1906."

Motor-car Race-track.—The inability of good macadam roadway to endure the effects of many motor-cars at high speed is shown in two striking photographs made by Cortlandt F. Bishop of Lenox and New York, whose world-wide road-pictures are noted as being unique. These were made in 1906 of a bend in a French broken-stone road, first shown in perfect form and then again two hours later when the smooth macadam surface had been torn up into windrows of loose fragments by the passage of an hundred racing motor-cars.

EXPERIMENTAL WORK.

These conditions and opinions have led to a great amount of experimental work, and to the invention of many processes and devices having for their object either temporary treatments which should hold the dust in place, or better, the adoption of more permanent methods which will prevent the formation of dust and which will be applicable to the many thousands of miles of existing fine roads of broken-stone which Europe has had for nearly a century and parts of America for one-tenth as long, and which must now be saved from threatened destruction.

In England.—The English engineers have had the advantage of an abundant and cheap supply of coal-tar, and have taken the lead in efforts to find ways to get the best results from applying it,—as well as various oil-emulsions,—to parts of their great extent of fine and old roads. A Royal Commission was appointed in 1906 to act upon the subject of dust prevention; the authorities being moved thereto by the wrecking of roads and the injuries to adjacent properties all over Great Britain. In July, 1906, an English engineer, Arthur Gladwell, of Eton, devised a method of using bituminous binder now known as the "Gladwell" system, which will probably be generally used to make a fixed and dustless surface on macadam roads, and which is described on page 111. Further, in May, 1907, the English Road Improvement Association held, near Reading in Berkshire County, competitive trials of the various machines and materials with instructive results, as noted at page 70.

In France.—The French engineers, whose national road system in its general scheme and organization and in the details of its execution and maintenance, is the finest in the world, have devised and widely used methods for applying bituminous binders and coatings to road surfaces (pages 65 and 69). Because of the increasingly destructive effects of motor-cars during 1906 and 1907 upon great lengths of the highways of France, the Minister of Public Works organized an International Congress to meet at Paris, October 11–18, 1908, under the direction of the Corps of Bridges and Roads: The "Adaptation of Roads to Modern Traffic" being considered and discussed in all its bearings, and the use of coal-tar and its derivatives both in original construction and as a surface application being given special prominence in the program—apparently because this material has so far given the best results on French roads.

In the United States.—Meantime, American engineers have produced the best form of bituminous macadam, or bitulithic, as well as the appliances for making it of uniform reliability and upon a large scale, and during the past seven years have built about five hundred miles of it in 166 cities of the United States and Canada (page 127).

Americans have also invented a method for the consolidation and asphaltic treatment of sandy and other soils, using a peculiar "rolling tamper" and heavy asphaltic oil, and have made in California many hundreds of miles of dustless roads which are comparatively cheap and which there, in the absence of heavy rains and deep frosts, are durable. This construction was extended during 1907 into Florida and

Michigan, in which later the effect of frost will be shown (see page 51).

CONCLUSIONS.

From the foregoing summary it appears that road-engineers who wish to improve upon these various methods which will be detailed, have ample field in which to experiment with advantage, while those who want to get results at once, and to check the damages by motor-cars and the complaints by property owners, can avoid methods which have failed elsewhere, and can use some of those which have already been found to be more or less successful, and which will be described.

MOISTURE.

WATER AS A DUST PREVENTATIVE.

The most common and the most costly way to prevent dust and to preserve roads is to sprinkle them with water. To keep roads always wet entails expense which is prohibitive even for city streets and park roadways, on some of which $700 to $900 per mile per year is expended for sprinkling thirty to forty feet width, in order to make them dustless during an average of six hours per day. During dry and hot weather the sprinkling to be effective must be repeated several times per day and the surface alternates between mud and dust. When tried on rural roads it has usually been ineffective, costly, and soon abandoned.

Sea-water is used with results even more unsatisfactory, for although the hydroscopic effect of the deposited salt prolongs the duration of moisture on the road, its presence in the dust and mud adds to their injurious effects; the salty, sticky mud damaging vehicles, corroding metals, and loosening the fragments of stone.

CALCIUM CHLORIDE.

This in solution is only to be regarded as a substitute for water, than which it gives better effect at about the same cost or sometimes for less.

MOISTURE.

Continuous moisture without frequent sprinkling is had by dissolving in water a dequilescent salt which is deposited in the road and attracts moisture from the air. Calcium chloride has, during several years past, been extensively used for this purpose on roads in England, where the moist climate and humid air offer favorable conditions, and where over two hundred of the local road authorities are using it increasingly, its weak solution as used being non-corrosive and harmless.

Calcium chloride ($CaC1\frac{1}{2}$) is a white or yellowish white, solid, translucent, dequilescent, chemical salt, which crystallizes in large masses and is a by-product of the ammonia process of making bicarbonate of soda from sodium chloride (NaCl) or common salt. It resembles rock-salt but is harder, and has a sharp, saline taste which burns the tongue. It dissolves completely in water in about three hours, leaving no residue, but it evolves heat and must be stirred to prevent caking. The cost in England at the Northwich factory (20 miles from Liverpool) is 30s. ($7.25) per ton, and in the United States at Carbondale, Pa., is $15 per ton f. o. b. cars. It is now available in granulated form, dissolving more readily.

METHODS.

It is sometimes furnished in a forty per cent solution which is diluted as desired, using more or less water as the character and condition of the road-material may require. The usual practice in England is to apply about three-fourths pound of the calcium chloride per square yard in the first treatment of a road, and at two-month intervals afterwards to apply about one-half as

much, or a total of 3 pounds per square yard per year, costing one cent per square yard per year for the chemical. On much exposed roads, threefold as much chemical is applied as often as needed to keep the road moist.

The success of this treatment in the humid air of England induced trials in the United States, and tests were made, in September, 1906, on the macadam and gravel roads of Beverly and Brookline in Massachusetts near Boston; the results were such that the treatment was extended during 1907 and continued in 1908.

At Beverly, Mass.—The treatment of the Beverly road is described by Franklin C. Pillsbury, Div. Engr. of the Mass. Highway Com., as being applied in September, 1906, to a good macadam road, built by the State in 1905, part of it entirely shaded and part open to sun and wind. As a result of the traffic of fast motor-cars passing almost continuously (six hundred and fifty being counted in ten hours of one Sunday), the road surface had lost its binder and the fragments of broken trap were exposed and beginning to ravel. The calcium chloride was bought in dry form from the Carbondale Chemical Co. of Carbondale, Pa., at three-fourths cent per pound f. o. b. cars. One application consisted in dissolving 600 pounds in 650 gallons of water by breaking the crystals into one and one-half inch pieces, or less, stirring for three hours; filling the tank of an ordinary watering-cart, and sprinkling it over 1400 feet in length of eighteen feet road; passing two or three times to saturate the surface. This equalled one-quarter pound of chemical per square yard. As a result, the dust and raveling ceased; the color was darker because of retained moisture, but it was difficult

to determine connection between this moisture and the humidity of the air as the season was not suited to observation. The application as above described was twice repeated during 1906 and the effect was good, especially on a portion of the road which was made of gravel. The treatment was continued during 1907 on ten miles of the same road, under contract calling for the chemical treatment supplemented by sprinkling with water. Two applications of the calcium solution were made in June, 1907, and one in each of the succeeding months to November 1, using one-tenth pound of calcium chloride per square yard each time. Water was sprinkled once on each dry day instead of four times per day as formerly. The contract cost was $331 per mile of surface averaging nineteen feet width, including watering as needed. The complete treatment costing about the same as, or slightly less than, the former sprinkling with water only. Dust was practically eliminated.

Improved Method.—In the 1907 work the crystals were dissolved at a "supply-station" and a saturated forty per cent solution was used to mix with the water in the sprinkling-tank, thus saving time and using a patented arrangement by which an ordinary water-cart thus equipped covers three times the area per day which was covered by the first method. Six galvanized iron barrels of 100 gallons capacity each are placed at hydrants about 1000 feet apart along the road, and are each filled with 40 per cent solution, brought in the watering-cart from the supply-station. Each in turn is then used, with water from the hydrant, to form 600 gallons of an eight per cent solution in the water-cart tank, which is then applied to 1000 feet of road. The contents of the six barrels thus treat one mile of nineteen-feet road for

each trip to the supply-station at a cost for treatment of two and one-half mills per square yard for each treatment. The total cost for the season of the treatment and of the watering, which together made the road dustless for five months, was three and one-eighth cents per square yard (or about $258 for one mile of standard 16-feet roadway).

The same roads were similarly treated in 1908 by the Calcide Process Company, of 402 Sears Building, Boston, Mass.

At Brookline, Mass.—The road treated at Brookline in 1906 is a part of Beacon Street, having a new telford roadway where a four and one-half per cent grade caused the many motor-cars to increase their speed to climb the hill with destructive effect on the road. The chemical was brought in a forty per cent solution and was diluted to eight per cent as before described, and was made to so saturate the surface that each particle should be coated with the chemical and thus kept moist, so that when dragged up by the suction of the broad rubber tires of motor-cars running at high speed, the damp particles should fall back onto the road to be again bound to the surface by the next pressure. Following English practice, a much heavier application was made than that just described at Beverly, with two applications in two weeks and then once in three to five weeks, according to the weather. The road was fully exposed to sun and wind and was free from dust when other parts of the same road needed sprinkling. The treatment was not continued in 1907 on this road.

CONCLUSIONS.

Tests have also been made elsewhere in the United States with varying reports as to results. The climate being less humid than in England doubtless accounts for less success. Its obvious advantages are that it is clean, odorless, and easy to apply, and that it is much better than water at no greater cost.

The process is best suited to special, limited cases of fine residence streets adjoining large cities where a municipal supply of hydrant-water is available for sprinkling, and it is specially applicable as preparation for parades or road-races. At the best, the effects of calcium chloride are temporary and make no radical betterment in the road surface. It is not applicable to the great extent of existing broken-stone roads which have no water-supply, and which demand permanent treatment to check wear in order to reduce dust.

SOLUTIONS.

This is more or less true also of other patented solutions, such as "*Akonia*," which has been used for several years on roads in Wembley Park and Harrow, England (near London), at a cost of about $194 per mile of sixteen feet roadway per year, which also keeps the road damp by attracting moisture; and "*Lymanite*," which is a combination, by heating, of nitrate of soda, salt, and lime, to which water is added when cold and which is then sprinkled; and "*Fitzsimmon's Patent dust-layer*," consisting of sand and soda fused and dissolved in water for use.

OIL EMULSIONS.

SUMMARY.

These are more easily and cheaply applied than oils. The use of emulsions avoids some of the obvious objections to the use of oils, which many however prefer. The effects of emulsions on road-dust are usually only temporary, but the results are immediate and travel is not interrupted.

There are in use many processes, patented and otherwise, for making and applying emulsions of oil, including vegetable oils, crude petroleum, residual oil, creosote-oil, oil-tar, coal-tar, and similar materials, in all of which cases some way is found to emulsify the oily or bituminous material in water, so that the mixture can be spread by a sprinkling or a spraying device, or usually by an ordinary watering-cart. The results are more lasting than those from the chemical salts just described. Most of them can be applied in any weather except during heavy rain, and there need be no interruption of traffic.

OBJECTIONS.

Many unsuccessful attempts have been made to use Pennsylvania and Ohio oils having a paraffin base, or some of the Russian oils, having a naphtha base, both

in their crude form and in emulsions; but these have all failed, because such petroleums are not suited to roadwork, refusing to bind the road materials, and having an ill odor.

Oils having an asphaltum base, like some of the petroleums of California, Texas, Indian Territory, Kansas, and Kentucky in the United States, and some from Galicia and from Baku in Europe, are the only ones suitable; but if any kind of oil is sprayed or sprinkled in its crude form on a hard macadam road, the result is liable to be most objectionable in regions of normal rainfall, which may mix the oil into injurious mud. In any case the greatest care must be taken to avoid getting the oil onto objects along the roadside, and to enforce rigid exclusion from the oiled surface for two or three days, or until all the free oil has been absorbed or covered. The difficulties of enforcing such precautions have led to the use of emulsions, which soak into the ground quickly and can be used in wet or dry weather, avoiding time of actual rainfall.

All of these oil mixtures in which acids or alkalies are used to form soapy emulsions which will mix with water, may be expected to cause the subsequent road-dust (even though it be slight in quantity) to be irritating and injurious to the throat, eyes, and skin, in proportion to the acridity of the solvent, and some of the mixtures have been disused for that reason.

METHODS.

Boston Park Roads.—"Cook's emulsion" is an old form, recently again used on the Boston park-roadways in September, 1906, and consisting of 100 gallons of

Texas asphaltic-base residual oil, emulsified with twenty-five pounds of coarse soap in fifty gallons of hot water. This was mixed with cold water in such proportion that the product contained fifteen per cent of oil and was applied from sprinkling-wagons to the hard road-surface which had been first covered with a thin, rolled layer of fine screenings to absorb the oil. Two and three distinct applications were made carefully; travel was not interrupted; the oil did not pick-up nor spatter; twelve miles of thirty-feet roadway so treated cost one and one-third cents per square yard, using 1.04 pints of oil per square yard. There was no dust during, nor after, six weeks, and the good effect continued. John A. Pettigrew, Supt. of Boston Parks, states that the best condition was obtained when the one-eighth inch layer of stone dust or sand was only so saturated with oil emulsion as to be like moist brown sugar; more oil was not desirable.

Cost.—At this rate the oiling of a sixteen-feet roadway cost $127 per mile, and four applications per year equaled $508 per annum per mile.

The treatment was extended during 1907 upon forty-four miles of park roads, nearly all of which were of hard, trap macadam. The soap used to emulsify the oil was made from cottonseed-oil and soda and was bought solid in barrels at four and three-fourth cents per pound. The oil was residual Texas oil from which the naphtha, kerosene, and volatile parts had been distilled until the residuum contained twenty-seven per cent of asphaltum, and it was bought from the Gulf Refining Company as "road-bed oil" at five cents per gallon in tank-cars. The emulsion was made by mixing eighteen pounds of soap with fifty gallons of hot water and mixing this with 100 gallons

of the oil by running them through steam-pumps. The stock thus made cost three and nine-tenth cents per gallon and was supplied to the ordinary sprinkling-wagons, in which water from the hydrants made the required solutions of sixteen per cent of oil for the first application, or of eight per cent or five per cent as required for the subsequent applications, which followed at intervals of ten days to twenty days, using a total of one and one-half pints of oil per square yard from April 15 to November 1, or six and one-half months, at a cost of two cents per square yard, or $187 per mile of sixteen-foot roadway; this included all except the cost of sanding twice during the season; meantime the asphaltum in the oil bettered the surface and less repairs were needed. The results of this oil-emulsion treatment were satisfactory and the dust was perfectly laid. The former cost of watering the same roads during a similar period had been three and one-third cents per square yard.

Conclusions.—Mr. Pettigrew considers that the use of the residual oil itself would be better than of the emulsion above described, but the emulsion permits that carriages may follow immediately after the sprinklers, whereas oil application would necessitate closing the roads for several days.

Chicago Park Roads.—Experimental work was done on the park roadways of Chicago during the spring and summer of 1907, having the primary purpose of laying the dust, using crude and residual asphaltic oils—alone, mixed, and in soap-emulsions of varied proportions. The object was to find a material which would not be sticky but would form a bond both below and above the surface and would permit travel to be uninterrupted and without injury. The roads were maca-

dam, part limestone and part granite; some bound with limestone screenings and some with gravel. The best results seem to have been had with a hot emulsion of Kansas fuel-oil (being a residual oil costing three and one-half cents per gallon from which the naphtha and volatile parts had been distilled), California asphaltum, ninety-eight per cent pure, costing ten cents per gallon, and soft naphtha soap of the "tak-a-nap" brand, which latter mixed best with the hard lime-water of Lake Michigan.

Mixture.—The emulsion was made by boiling sixty gallons of water with live steam and adding fifteen pounds of soap and boiling five minutes; adding sixty gallons of the Kansas residual oil and pumping them from one vat to another for five minutes to mix; then adding twenty-five gallons (half a barrel) of California asphaltum, ninety-eight per cent pure, and pumping the whole for twenty minutes to emulsify the mixture, which cost six and one-quarter cents per gallon. This was then sprinkled upon the thoroughly cleaned and swept surface of the hard macadam roads at the rate of one-fifth gallon per square yard for each coating, and five of these coats were applied in as rapid succession as possible. Meantime any small holes in the surface were filled with sweepings from the roadside to be cemented with the next hot emulsion application. Roads treated in this way in Lincoln Park on June 19, 1907, remained dustless and in good order until the middle of October, or for four months, with no other treatment. Traffic continued during and after the applications with no bad results, and there was no bad odor.

Cost.—The cost of this work was excessive, being at

the rate of $586 per mile of sixteen-feet road for the emulsion alone, to which was to be added the cost of application and of patching.

WESTRUMITE.

"*Westrumite*" is a patented emulsion of petroleum and ammonia, forming a sort of soap which is soluble in water. It was invented in Germany, extensively used there and in England (especially on stretches of road to be used for parades or for motor-car races), and was first brought to the United States in 1905, when it was used experimentally on Staten Island, N. Y., and on the Midway Plaisance in Chicago.

It is designed to suppress dust on any kind of road, preventing soakage of water and acting somewhat as a binder. It has a disagreeable odor for two days after application, and makes a macadam roadway somewhat slippery.

At Chicago.—On the Midway Plaisance the traffic was restricted to carriages, motor-cars, and bicycles. The roadway was of limestone macadam bound with limestone screenings, and was very clean when it was first sprinkled with westrumite on August 21 and 22, 1906. A ten per cent solution (one part westrumite to nine parts water) was applied from ordinary watering-carts, 0.31 and 0.175 gallon of the solution per square yard being used for one application. At successive intervals of about eight days the application was repeated, using 0.17 gallon (or one-sixth gallon) of a five per cent solution per square yard, the cart passing twice to make each "application," of which ten in all were made during eighty-three days, during which time, night and

day, there was no dust. The added cost to that of using plain, free water was two and two-tenths mills per square yard per month, or forty-five per cent more than for free water only. This cost is based upon a rate of seven and one-half-cents per gallon, or $20 per ton, for the westrumite, and equals $21 per month per mile of a sixteen-feet roadway. Park superintendent J. F. Foster considers that if the traffic had been unrestricted and heavy, the applications needed to give the same results would have been double the above-named amounts applied at four-day intervals, equaling fourfold the above cost.

In Europe.—In France, "westrumite," or some one of several similar compounds (one known as "coudrogenit") is much used to control dust for special occasions of short duration, and various devices other than the common watering-cart are used. On parkways and suburban roads where water-mains are at the roadside, water under pressure is sometimes lead through a hose to a special nozzle into which oil, or westrumite or other emulsion, is fed by a branch pipe from a reservoir which is sometimes carried like a knapsack on the back of the man holding the nozzle, or from a barrel drawn on a hand-cart by another man. The special nozzle consists of two conical pieces fitting together so that the water stream acts by aspiration to draw the oil or emulsion, which then mixes with the water in the nozzle and is spread upon the roadway.

In Germany trials of westrumite on roads in and near Dresden (as reported in the Minutes of the Inst. of Civil Engineers of Great Britain for December, 1907), gave results which were in every way satisfactory as to prevention of dust; but the cost was four to six times

as great as that of ordinary watering, so that there was no general use because of the prohibitive expense.

In the United States.—The excessive costs for the transient results seem likely to limit the use of "westrumite" in the United States to special cases and to emergencies, especially as more permanent or more effective methods are coming into use.

In 1907, westrumite was used in a different way at St. Paul, Minn., to saturate the layers of a granite macadam road during its construction. A ten per cent solution of westrumite was sprinkled on the crushed stone before and during rolling, and a fifty per cent solution on the limestone screenings binder, and a fifteen per cent solution on the surface of the finished road, aggregating about one gallon per square yard. This treatment must have added twelve cents per square yard to the cost of the completed road, which is said to be kept free from dust by sprinkling with water once in ten days.

PATENTED EMULSIONS.

"*Westrumite* 2" is a similar ammonia emulsion of natural bitumen, used in a somewhat similar way for the same purposes.

"*Pine-oiline*" was a preparation similar to westrumite, but its manufacture has been joined with that of the latter.

"*Apulvite*" is a similar product which was used in Geneva, Switzerland, as was westrumite; but each failed there to give the expected results as they did not resist rainfall.

Another patented soapy mixture is "*Sandisize,*" formed by mixing potash with the by-product of wool-washing

wastes left after extracting the major part of the grease. It is said that the resulting emulsion does not clog the sprayer and that it has marked hygroscopic properties. It was originated and first used in Scotland in 1905, where it was patented, and it is also patented in the United States. The treatment in Scotland of one mile of sixteen-foot roadway with ten per cent solution costs for one application $21.50; three or four applications per season preventing dust.

"*Crempoid D*" is a mixture of glue and bichromate of potash, with oil added to soften it, and it also is applied from a spraying-machine, or in a weak solution from a watering-cart, and has been tried at Islington near London, and at Bladshall in Midlothian. It was entered in competitive tests before the English Roads Improvement Association in May, 1907, and was reported to have practically disappeared from the road in a fortnight.

Other crude oil emulsions or mixtures are the English "*Dustabato System*," "*Newstrand*," and "*Riley's Compound.*"

"*Dustoline*," an American preparation made in Summit, New Jersey, is a thin, clear, yellow oil having no "body" which can furnish any mechanical bond of the road-material. It was used in 1907 on about five miles of macadam roads at Newport, R. I., in two applications, two weeks apart, without removing the layer of dust, using from one-fourth to one-fifth gallon per square yard for both, at a total cost for material and labor of three and one-half cents per square yard. It costs seven and one-half cents per gallon in car and is said to be effective in laying dust, and to be perfectly satisfactory to the local officials, but to have had injurious effects on rubber tires and on clothing.

"*Terracolia*" is an ammonia emulsion of oil (with ten per cent of coal-tar), and is a thick, brown, molasses-like mixture. It was used during 1907, in five per cent and twenty per cent solutions, in Montclair, New Jersey, and in Prospect Park, Brooklyn, and in Bronxville, New York, and near Boston, and is said to have given good results in laying the dust, but at high cost.

"*Pulvicide*" is an English compound composed of coal-tar creosote 50 gallons, coal-tar pitch 112 pounds, resin 252 pounds, which are mixed and heated until solution forms. Twenty-eight pounds of caustic soda is then dissolved in eighteen gallons of water and poured into the former mixture, stirring until combined. The resulting emulsion is mixed with water, usually in the ratio of thirty gallons to 300 gallons of water, and this is sprinkled over the road-surface from an ordinary watering-cart, with the result of depositing the contained bituminous material on the surface, where it has proved effective in laying the dust for periods of ten days, after which another application is made. During 1906 it was used by forty or more road authorities in England at costs not stated. It was entered in competitive tests before the English Roads Improvement Association in May, 1907, and was reported to have practically disappeared in a fortnight.

"*Ermenite*" is an emulsion of cottonseed-oil, coal-tar, and soap. It is formed by treating hot cottonseed-oil with sulphuric acid, and then washing and mixing it with four times its weight of crude tar. This mixture is then emulsified with hot caustic soda and is then diluted with water until it contains twenty per cent of tar. This twenty per cent solution is mixed in the tank of an ordinary watering-cart with four volumes of cold water

and is sprinkled on the road without mechanical stirring. It was used during 1906 at Holmes Chapel in Cheshire, England, at a cost not stated. When applied in the competitive test as described, it disappeared from the road in a week.

"*Hahnite*" is an emulsion formed by mixing oil and carbolic acid heated to 150° F., with asphalt and tar, without saponifying the oil. This is mixed with water in an ordinary watering-cart equipped with a mechanical stirrer actuated from the wheel-axle, and is sprayed upon the road where it oxidizes, with the effect of laying the dust. It has been used in England in Surrey, at Richmond on the Petersham road, and by the Kingston Corporation on the Riverside road, all suburbs of London. In the competitive test above described, it had practically disappeared from the road in a month.

"*Rapidite*" is a French compound of powdered asphalt mixed with water, probably containing an acid or an alkali as an emulsifier.

CONCLUSIONS.

None of these emulsions claim to be of more than temporary effect, and in regions like the south of France and in the French and Italian Riviera, the winter playground of Europe, the good temporary effects on the roads have in some cases been offset by the injurious effects to the road-users, as stated on page 25. In regions of heavy or frequent rainfall, the necessity for renewal after rains has added to the cost of their use. They do not seem to be generally adapted to American conditions.

MECHANICAL EMULSIFIER.

Good results were expected from an English machine known as the "*Emulsifix*," by which tar-oil or other road-oil is mechanically emulsified in water without the objectionable aid of acid, alkali, or heat; the mixture being sprayed upon the road before it could separate. This machine, having been elsewhere used, was entered with seven others at the competitive trials and tests before mentioned which were held by the English Road Improvement Association near Reading in Berkshire County on May 24-27, 1907. It then failed to give satisfactory results, but some later modification in machine or material may supply the lack then shown.

Method of Operation.—It consists of a horse-drawn wagon carrying a large tank divided into two compartments, one for water and the other for oil-tar or oil; a smaller and separate tank is in the rear, in which the oil and water meet and are there mixed by rapidly revolving blades actuated from the wheel-axle, forming a mechanical emulsion which is forced through a pipe in a finely subdivided state onto and into the road-surface. No heat is used, and valves regulate the proportions mixed and the quantities used. Tar-oil carrying forty per cent of tar is preferred for use in the "Emulsifix," and the treatment consists in applying two coats of five per cent emulsion on two consecutive days, and afterward at intervals of a fortnight or three weeks as required.

Results.—There is no need to close the road while the treatment is in progress, and one wagon is said to suffice to keep fifty or sixty miles of road in good condition

with eight treatments per annum, at a yearly cost of $35 to $50 per mile of twenty-four-feet road.

The machine is said to have given good results at Knutsford, Whitington, and Chilford, all near Manchester; but the adverse report of the Road Improvement Association judges will cause these claims to be questioned. Such results as are claimed would be very desirable and the device seems to have capabilities worthy of improvement, as its success would enable the use, at low cost, of oil emulsions free from acids.

OILS.

SUMMARY.

Attempts have been made since 1894 to use crude petroleum or some of its derivatives, or some oily by-product of gas manufacture, to control and prevent dust. These attempts, many of them unsuccessful, have led to knowledge as to the kinds of oil which are unsuitable and as to the conditions which cause failure (page 25). Experience has also shown that oils of certain characteristics, properly applied under the right conditions, give good results at reasonable costs. There will undoubtedly be a great increase in the near future in the use of heated asphaltic oils, not only to prevent dust but also to improve sandy roads and to preserve gravel and broken-stone roads, though there are as yet but few examples of the latter (see page 42).

PETROLEUM.

Crude petroleums, which contain the largest proportion of pure asphaltum, give the best results. Petroleum, without asphaltum, having a paraffin base, like the Pennsylvania and Ohio oils, and those having a naphtha base, like some of the Russian oils, are useless, refusing to bind and having ill odors and making greasy slime. Some of the California oils as they come from the wells

contain so much asphaltum that they are valuable mainly for it; some of the wells in the Bakersfield district (100 miles N.N.W. of Los Angeles), especially the "Adeline" wells, produce petroleums having sixty to eighty-four per cent of pure asphaltum. Such crude oils are there used on roads with good results not otherwise equaled, by following methods described on page 51.

Residuum.—Petroleums with asphaltic bases from the Beaumont fields of Texas and from Kentucky, Kansas, and Indian Territory, and some of the Russian oils from Baku, and those from Galicia in Austria, and from Borneo in the the far East, which are mainly valuable for their volatile parts, leave residuum which is effective for roadwork after distillation has removed the naphtha, gasolene, illuminating-oil, and other elements which would be detrimental for roadwork. The by-products thus left are variously known as "residual oil," "roadbed-oil," "fuel-oil," "steamer-oil," and other trade names.

Test.—These are usually thick, black or brown viscid substances, whose proportion of asphaltum can easily be determined by evaporating a weighed sample in an open, metal pan over gentle heat until the residuum has the hardness of commercial "D" asphalt at the standard temperature of 60° F. The weight of this residue compared with the original weight of the sample before evaporation should show twenty-five to twenty-eight per cent, or better, forty per cent. With less than twenty-five per cent it is not well suited to roadwork. Some samples so tested will show no asphaltum whatever, although there may have been reason to expect to find it. Test should also be made for the amount of contained water, which should not exceed two per cent.

Slow distillation.—It is observed that the residuum from oil which is light in asphalt is better suited for road-work when the distillation is done slowly, and at lower temperature than generally used by the refiners when the production of gasolene and illuminating-oil is the main object, and when the ill effects of high heat on the asphaltum are not considered. When the distillation is done at 300° F. instead of at 600° to 700° F., two days are required instead of one day to do the refining; but the resulting asphaltic residual oil is much better for road-work, and more nearly resembles the naturally heavily asphaltic oils of California, the contained asphaltum showing much more of the great ductility of the California asphaltum, which largely accounts for its success in road and pavement work.

CALIFORNIA PETROLEUM SHIPMENT.

California crude petroleum, heavy in asphaltum which is ninety-eight per cent pure, may at some future time be available for that general use which is now prevented by difficulties of transportation. Railroad rates across the continent are prohibitative, and the ordinary eight-inch pipe line which crosses at Panama and supplies fuel-oil to the canal works has not yet been used to pass this heavy, thick oil for road work, it having been found in California that delivery through such a line is too slow to be practicable even under the most favorable circumstances. This led the Southern Pacific Railroad to begin building, in 1907, a 282-mile specially designed pipe line for delivering this heavy oil at Porta Costa on an arm of San Francisco Bay. This line is an eight-inch steel pipe rifled with six grooves making a complete turn

every ten feet, giving a rotary motion to the stream. Ten per cent of water introduced with the oil is found to be thrown by centrifugal force to the outside of the stream of oil, where it acts as a lubricant between the oil and the pipe, reducing friction and facilitating the passage of the oil without the need for heating it, as has formerly been tried. The pipe line is expected to be in operation in 1908, so that tank-ships may be able to deliver the oil at reasonable cost at Atlantic ports.

Substitutes.—Until such time there is no reason why the best Kentucky, Texas, or other asphaltic petroleums, when refined by the slow process as above, should not produce an asphaltic residual oil which will give good results when properly used (see page 52).

FAILURES.

It has been a common thing during the past few years for some county official, to whom all oils look alike, to buy a car-load of oil of unknown quality and to have it sprinkled from watering-carts in unrestricted quantity, without experienced direction or regard to details of road condition or of weather, and without attempt to remove or to cover the greasy mud caused by sudden rainfall, or to warn the traffic to avoid the fresh oil. The results have often been most objectionable to residents and to road-users, and have caused opposition and waste which good management would have avoided. One writer says:

"The ordinary road sprinkled with petroleum is probably the most obnoxious possible. The oil is everywhere—on plants, bushes, trees, vehicles, and clothes."

Such criticisms are based on reason, but the objectionable features are avoidable. There have been failures from applying oil during cool weather or upon roads not thoroughly dry, and from the effect of rain soon after application. Rain tends to form an emulsion with the free oil and makes a sticky, injurious mud, and leaves the road-surface soft (see page 15).

HISTORY.

Crude petroleum was probably first used for road work at Santa Barbara, California, in 1894, and its use in that State has since been general and in most cases successful. The success has been primarily due to the peculiar character of some of the local petroleums of which, as stated on page 38, there are those containing forty to eighty-four per cent of pure asphaltum, coming from the wells as a thick, viscid, black liquid, which looks like molasses and must be heated to give it the fluidity necessary for use; some contain no asphaltum and are useless for road work. The good results from oiling California roads are due secondarily to the semi-arid climate, characterized by dry, hot periods without rain, and to the methods and appliances locally evolved for forming durable, dustless roads of oiled and tamped sand or earth, as described on pages 51, 55.

PRESERVATION OF PRESENT ROADS.

The present interest, however, attaches mainly to the treatment of the surface of existing standard, macadam and telford roads, formed of hard, crushed rock, located in the central, southern, and eastern States, and in

Europe, where the peculiar California oil is not yet sold, and where asphaltic residual oils like some of those from Texas, Kansas, Kentucky, and Indian Territory for the United States, and from Galicia in Austria, and Baku in Russia for Europe, are the only ones available.

OIL ON STONE ROADS.

There are but few instances of such successful use, some of which are described in order of date.

IN RHODE ISLAND.

The town of Cranston, Rhode Island, has thirty miles of macadam roads formed of the native blue granite, which is not quite so hard as trap, of which granite the roads of Cranston have been built and maintained since 1890 by P. J. Conley, highway surveyor. As the town adjoins the City of Providence, some of these roads are trunk lines subject to heavy commercial traffic, and they are also subject to the motor-car travel incident to such location. Since 1900 Mr. Conley, induced thereto by accounts of success from oil treatment in California, has each year sprinkled these roads with residual Kansas asphaltic oil (with probably twenty-five per cent asphalt) bought from the fuel-oil department of the Standard Oil Company at Bayonne, New Jeresy, for four and six-tenths cents per gallon, f.o.b. cars at Cranston.

Cost.—This has been applied cold from an ordinary sprinkling-cart, when the roads were perfectly dry, using about one-seventh gallon per square yard, or 1200 gallons per mile of road, at a cost of $60 per mile for each application.

Results.—Two such applications have usually been made each year. One sufficed in 1907. Dust has been controlled. Some damage was done to motor-cars, carriages, and clothes during the three or four days following an application, and during and immediately after hard rains, by the picking-up of coagulated, oily dust; but that the results on the whole have been satisfactory is shown by the continuance of the treatment from year to year for eight consecutive years. The cost has averaged $120 per mile per year, or one-sixth the former cost of watering. It has without doubt increased the life of the road, but the tenacity of the asphalt in the oil is not sufficient to prevent ravelling under unfavorable conditions.

IN ENGLAND.

At Liverpool, England, in 1902, and during two years following, experiments were made on fine macadam roads by applying various oils and mixtures, hot and cold; among others was crude Texas petroleum. The importance of the contained asphalt was not then appreciated and no record was kept of this feature. Applications were made during dry weather only, using in 1902 an ordinary hand-watering can and spreading one-eighth gallon per square yard. Of the six materials tried, petroleum was the least satisfactory. In 1903 it was again applied, through hand-syringes with fine roses, using one-eighth gallon per square yard, costing one-fourth cent, at intervals of three weeks. The conclusion was that "creosote-oil" was better, as described on page 62.

IN AUSTRALIA.

In 1903, at Sidney, N. S. W., Australia, macadam roads of very hard bluestone were oiled, and the details are given by John Colin Rose, Assoc. M. Inst. C. E., borough engineer of North Sidney. The oil was residual, from an asphalitc American petroleum left after the extraction of the volatile parts, and consisted of part of the petroleum with vaseline and bitumen. One-fourth gallon per square yard was applied cold from hand-watering cans with small perforations, as this method was found to best avoid excessive and unequal distribution and to be the cheapest and most effective way. It was, however, found necessary to shield the rails of the electric street railway during the operation of oiling. The work began in November (the commencement of the Australian summer), and was confined to dry days, as it was found that, if a heavy shower immediately followed the oiling, the operation was wasted and that the oil was washed into the gutters.

Cost and Results.—With labor at twenty cents per hour and oil at six cents per gallon, the cost per square yard was one-fourth cent for labor and one and three-eights cents for oil, or one and six-tenths cents total. The results were that the cementing cushion formed by the bitumen caused the fragments of stone to cohere, thus reducing the noise of traffic, banishing mud and dust, increasing the life of the road, and reducing the cost of maintenance. These results lasted after each treatment for a minimum of two months to a maximum of four months. In 1906 one of the roads which had

been thus treated for two and one-half years remained in first-class condition, with the binding material plastic and much like india-rubber.

IN TENNESEE.

At Jackson, Tennessee, in 1905, the U. S. Office of Public Roads, Logan Waller Page, Director, did some instructive work and used a number of materials upon macadam roads; among them were crude and residual Texas and Louisiana oils.

Light Crude Oil.—The light, crude oil was applied to the cleanly-swept surface of the macadam, into which forty-eight one hundredths gallon per square yard soaked very quickly and left no asphaltic coating on the surface. It was first applied from a hose attached to a tank-wagon, fcllowed by nine men with brooms to spread it by sweeping; this cost fifty-seven one hundredths cent per square yard for the labor only. A street-sprinkler operated by one man, then spread 600 gallons of oil over 1200 square yards of road in fifteen minutes, or more than twice as rapidly as the tank-wagon and nine men. This light, crude oil produced slight effect, and it was decided that the oil was too volatile for the purpose and that the results did not justify the expense of distant shipment.

Residual Oil.—The heavier medium grade of Texas "steamer oil" was then applied hot from a street-sprinkler, the best results being obtained at the highest temperature. The heating must be done with steam coils to avoid danger from fire. The force employed consisted of a foreman and six laborers, costing $9.50 per day; one tank-wagon and one street-sprinkler,

costing $6 per day; two firemen, costing $3 per day; and one ton of coal at $4; or a total of $22.50. This applied 3300 gallons of oil per day at seven-tenths cent per gallon for application. The cost of the oil will vary with the locality, but at five cents per gallon and using three-fourths gallon per square yard, the total cost including labor equals four and one-fourth cents per square yard. The results of applying the Texas "steamer oil" to the macadam roads were good. The "wearing coat" of one-eighth inch of road-dust (which was left on the road) was saturated with the oil and made to cohere, forming a protective coat of oil-compacted dust which tended to prolong the life of the road. In 1908 two and one-half years later, the city engineer of Jackson reported that the crude oil and the "steamer oil" had left no appreciable effects.

Heavy Residul Oil.—The heaviest residual oil, much thicker than "steamer oil," gave the best results, and required heating to enable it to flow, working best when at or near boiling-point. When applied cold it formed a thick, sticky mass, which rolled about on the road so that its removal was necessary. When applied hot the oil flowed freely from the tank-outlet, was spread by hand-brooms, and was absorbed more or less into the road, and after twenty-four hours was covered with sand and screenings; after four days it did not show wheel-tracks. The macadam roads thus treated with oil were made entirely dustless, and they could be cleaned and swept as well as the tarred roads. The total cost, as before itemized, was about four and one-half cents per square yard.

These results at Jackson have been widely published and have been most useful, forming the basis for much

road work in many parts of the United States. Under date of February 25, 1908, the city engineer reported that good results from the heavy residual oils were still apparent after two and one-half years, the roads treated with them being still practically dustless.

IN CALIFORNIA.

In 1906 the city of Pasadena, California, following the practice which had proved successful in Riverside, California, treated the surface of new macadam roadways with crude asphaltic petroleum containing eighty-five per cent of asphaltum. Of this, one and one-fourth to one and one-half gallons per square yard were applied hot to the protective layer of sand which covered the roadway, forming a thin carpet or wearing surface which makes the macadam noiseless and dustless. The added cost did not exceed three cents per square yard. T. D. Allen, city engineer of Pasadena, described the work in a paper before the annual meeting of the American Society of Municipal Improvements.

IN RHODE ISLAND.

In 1907 the State Board of Public Roads of Rhode Island treated the State road in the town of Barrington, R. I., with asphaltic Texas "petroleum residuum," from the Standard Oil Company's works at Bayonne, N. J. One-fifth gallon per square yard was sprinkled cold upon the road with its normal dust in place. The cost of the oil, delivered in car, was four and six-tenths cents per gallon; the total cost of the treatment including oil and labor was one and one-twentieth cents per square yard, or $103 per mile of sixteen-feet roadway. The

results were satisfactory (being similar to those already described on page 42 for roads in Cranston, R. I.), and are detailed by Asst. Engr. Arthur W. Blanchard, Assoc. Prof. of Civ. Eng'g. at Brown University, who gives valuable information in his paper before the Amer. Assoc. for the Advancement of Science, with analyses of the various oils, tars, and preparations which were used under his direction. His opinion is further quoted at page 84.

IN ILLINOIS.

In 1906 and 1907 part of the macadamized Sheridan Road between Chicago and Evanston was treated with asphaltic oil, and has since been in use by thousands of motor-cars daily. *Municipal Engineering* describes the conditions on September 16, 1906, when the roadway was covered with motor-cars. The oiled portion was free from dust and the blue sky was to be seen through the clear air; while on the parts not oiled, the motor-cars disappeared in clouds of dust which obscured the sky. In July, 1907, the oiled portions showed the effects of motor-car tires. The details and the cost of the treatment are not given, but evidently the effects were good but not lasting.

IN SOUTHWESTERN STATES.

In a paper before the 1906 meeting of the American Society of Municipal Improvements, Walter F. Reichardt, assistant city engineer of Little Rock, Ark., stated that Texas asphaltic oil is much used, with good results, on the macadam roads of the small cities of the Southwest, where chert and trap from Missouri and Arkansas are available.

IN MASSACHUSETTS.

During 1907, a fifteen-feet macadam roadway in Beverly, Mass., was treated with residual Texas oil containing twenty-seven per cent of asphalt, sold by the Gulf Refining Co. (514 Battery Park Building, New York City), as "roadbed oil" at four and one-half cents per gallon. The details of the treatment were described at the November 12, 1907, meeting of the Massachusetts Highway Association in Boston, by Col. W. D. Sohier of Beverly. (See page 13.) The broken-stone roadway being hard, dry and well-crowned, was swept clean.

Precautions.—Between the hours of 10 A.M. and 3 P.M. of hot, dry days, heated oil was sprinkled from an ordinary "half-moon" sprinkling-cart of which the outer holes were plugged so as to limit the width sprinkled to ten feet, thus avoiding spreading the oil upon the edges of the road near the gutters. Six men preceded and swept the road preparatory to the oiling, and two men followed with brooms and swept and spread the oil over the surface; part of the six men first mentioned also scattered screened fine gravel over the fresh oil, using one cubic yard to cover forty square yards of surface; half a gallon of oil per square yard was thus applied and covered at a total cost including oil of from four to six cents, or an average of four and one-half cents per square yard. Special care was taken to avoid oiling damp or wet spots where the oil would only make an oily mud; and particularly was it required that only as much road should be oiled as could be covered and completed before night, because if rain came on the oiled road before it was covered with fine gravel, the oil would

float off and form an objectionable, oily mass which must be removed from the roadside.

OILED SCREENINGS.

At the same meeting, Charles W. Ross (see page 83), described an effective manner in which he used the just-described "roadbed oil" on a trap-rock macadam road in Newton, Mass., during 1907, by mixing twenty gallons of hot oil with one cubic yard of heated screenings until the oil was thoroughly mixed through the mass, which was then spread with shovels over a layer of three-fourths inch stone, and the whole then rolled. This was done in June, 1907, at a total cost of twelve cents per square yard, including stone, screenings, oil, and labor. The road was not watered during the succeeding five months, and there was no dust, and it was satisfactory to a very critical community. Mr. Ross further states that the oil sprinkled over the surface of a macadam road (at a cost of about two and one-half cents per square yard) does not save the road from wear but merely stops the dust; and that a light coating of sand shaken over the freshly-oiled surface was found to stop spattering of the oil, regarding which complaints were otherwise made.

IN NEW YORK.

During 1906 the State Engineer Department of New York oiled several State roads, using crude asphaltic Kentucky oil, known as "Raglan oil," supplied by the Standard Oil Company at four and three-quarter cents per gallon, delivered on car, containing thirty to thirty-five per cent of asphalt. Five macadam roads were treated with an average of one-fifth to one-fourth gallon of heated

oil per square yard, by means of a "White" machine, at an average cost of $128 per mile of sixteen-feet roadway. The oiled surface was covered with one-quarter inch of sand five hours or more after application, preventing spattering of free oil. Dust was stopped for some weeks, and the general effect seemed satisfactory.

CALIFORNIA OILED ROADS.

Summary.—Types of oiled roads peculiar to California have been evolved from the local conditions of material and climate, as stated on page 41. The results have been such as to induce efforts to adapt the best of these constructions to other conditions elsewhere.

Methods.—The best system is known as the "Petrolithic," and consists in mixing three and one-half to four gallons of seventy to eighty-four per cent heated asphaltic oil, with each square yard of surface of loosened, moistened soil (preferably sandy and surfaced with gravel, though even adobe clay is possible), and consolidating with a patented "rolling tamper" into a firm, smooth, six-inch layer, which is durable and dustless.

Cost.—"Petrolithic" roads have been built during several years past in thirty California cities and their suburbs at costs varying from twenty cents to thirty-six cents per square yard, indicating an estimated cost of forty-five cents to fifty cents per square yard in the Eastern States (see page 54). Oiled earth roads in the Eastern States, similar to the "petrolithic" roads, were advertised in 1908, by the Imperial Paving Company of New York City for the States of New York, Connecticut, and Rhode Island, and by the Good Roads

Paving Company of Kansas City, Missouri, for other States. The cost is stated to be that of good macadam, and the method uses the "tamping roller," and binds the soil with liquid asphalt dissolved in crude Kansas or Texas asphalitic oil.

Oiled crushed-stone roads and gravel roads have also been built (see page 56).

Many miles of rural earth or sand roads in California have been treated with one gallon per square yard of forty to seventy per cent asphaltic crude oil, some hot and some cold, using a grader and a drag, at one-twelfth of the above cost, or $150 per mile (see page 55).

SUBSTITUTES.

It is probable that similar results may elsewhere be had with the residuum of other asphaltic oils, or with coal-tar preparations like "tarvia" (page 74). It may be, also, that commercial asphaltum derived from California oil may be liquified with about forty per cent of Texas or Kansas crude oil, so as to be like the California oil. But nature's combinations are difficult to imitate—it is not always possible to tell by analysis why one oil, or tar, succeeds and another fails; and such efforts to imitate California oils are as yet experimental (see page 39).

The "White" machine for sprinkling oil is generally used, as described on page 88.

PETROLITHIC PAVEMENT.

Methods.—The following describes the best "Petrolithic" pavement: The roadway is properly formed and rolled, when dry, until solid, and all depressions are

filled and tamped. The surface is then ploughed to a depth of six inches and the loosened earth or sand thoroughly pulverized by repeated passages of cultivator or harrow, and all stones of two inches diameter and larger removed. The roadbed is then sprinkled with sufficient water to evenly dampen the top four inches and this depth is then worked with a lightly-set cultivator to loosen and mix the earth and water to a uniform dampness.

Oiling.—Upon this damp surface is then sprinkled crude oil containing not less than sixty-six per cent of soft "D" grade asphalt, nor over two per cent of water, the oil being heated to not less than 100° F. nor over 190° F., and being evenly spread at the rate of one gallon per square yard of surface. This is then thoroughly cultivated ten times, or until well mixed to a depth of four inches. A second similar coat of oil is then spread and turned to a depth of four inches in the same way, until the oil and the soil are well mixed; going over it with a cultivator at least ten times after each coating or until every particle of soil is coated with the oil. It is then ploughed four inches deep with a plough that thoroughly turns the furrows.

Tamping.—The "rolling tamper" is then applied, beginning the tamping at six to seven inches depth and tamping solidly upward to within two inches of the top. The surface is then evenly covered (if gravel is available) with two inches of hard gravel, one-quarter inch to one and one-half inches in size, and this is thoroughly mixed by cultivator, with the top loose two inches of the oiled soil, using care meantime not to disturb the tamped base. There is then spread over

the gravel surface one and one-half gallons of the same hot oil per square yard, and the whole again tamped with the rolling tamper until the entire surface is uniformly hard and solid; an ordinary ten-ton roller is then used to smooth the surface.

The "rolling tamper" mentioned is a peculiar and patented horse-drawn roller, manufactured and sold by the Petrolithic Pavement Company of Los Angeles, California, at $750 f. o. b. cars. It is about eight feet long and five feet in diameter, weighs about 5000 pounds, and is made in two sections for ease in turning around. The outer surface is studded with iron legs, each pro-

ROLLING TAMPER.

jecting seven inches, the outer end of each leg being like a sheep's foot, about two inches by three inches. There are fifteen of these legs in each of twelve rings, or 180 in all, and they are forced into the pulverized and oiled earth and gravel by repeated passages over the road until it is packed to the top, so that the feet ride upon the hardened surface. Should excess of oil then appear, sufficient clean, sharp, coarse sand to absorb the oil is spread over the oily surface, which is then rolled until solid.

Cost.—With oil costing seventy-two cents per barrel of forty-two gallons, such roads have cost an average of

twenty cents per square yard, varying up to thirty-six cents per square yard with the conditions and cost of oil. Such roads have been successfully built in Los Angeles upon adobe clay, which is a most difficult material.

OILED RURAL ROADS.

Cheaper and simpler construction has been used to make a thousand or more miles of oiled country roads, as described by the California State Highway Commissioner, N. Ellery. The earth road being properly drained, formed, crowned, and made solid, each square yard of its surface is sprinkled with one gallon of cold crude asphaltic oil having at least forty per cent of asphaltum, or more, if such is obtainable; this to be determined by tests as detailed on page 38. If it contains more than forty per cent, heating will be necessary to give fluidity. As soon as the oil is spread over the roadbed it is covered at once with four inches of earth from the roadside, or preferably with sand or fine gravel, if obtainable. It is then compacted by rolling with an ordinary roller, horse-drawn or steam-driven, using a grader and a drag to keep the road-surface smooth, until the oil eventually comes to the surface as the material packs under rolling and use, oily spots being meantime covered with sand. This treatment is said to be given at a cost of one and one-half cents per square yard, or $150 per mile; but it is evident that this figure must be increased if much rolling is done. It requires to be followed by frequent and careful use of the grader and drag, and many such roads have failed for lack of this care. When well built and maintained, the effect is to reduce the dust and

improve the road; but of course these cheap roads are in no way to be compared with the "Petrolithic" roads before described, nor with the hard gravel or stone roads used elsewhere. If the natural earth roadbed is of alkali soil, other soil must be spread over it, as alkali disintegrates the asphalt in the oil.

Oiled gravel roads are also used in California, and Commissioner Ellery describes their construction. Upon the formed sub-grade compacted by the usual wetting and rolling, there is spread the coarser portion of screened gravel, four to five inches deep. This is rolled with a ten-ton roller, and one gallon of oil having forty per cent or more of asphalt is applied per square yard of surface. This is at once covered with three inches of the finer portion of the screened gravel and rolled until compact, the oil tending to work upward into this top layer as it packs.

Oiled broken-stone roads are similarly made, with the usual base course of four to six inches of the one and one-quarter inch to two and one-half inches of loose, crushed rock, which is sprinkled with water and rolled in the usual way. On this, when dry, there is sprinkled one gallon of heated, heavily asphaltic oil per square yard of surface, which is at once covered with two inches of three-quarter inch to one and one-half inches crushed rock over which there is spread one inch of screenings of the same. The road is then rolled thoroughly with a ten-ton roller until the oil shows in the screenings. Where oil comes to the surface the spots must be covered with more screenings. In the case of either gravel or broken-stone roads thus oiled, the added cost is that of the oil and its heating, less the saving in water.

REPAIRS OF OILED ROADS.

All oiled roads need close attention and prompt repairs. Ruts and weaks spots must be cut out, leaving vertical sides; the cut must then be filled with the material of the road,—sand, or fine gravel or fine stone, as the case may be,—mixed with oil. This added material must be slightly higher than the surrounding surface, after oil has been poured upon it, and it has been thoroughly packed with a hand-tamper.

Oiled roads thus built and cared for in California have proved to be great improvements upon their former conditions, and to be comparatively dustless. The careless sprinkling of California asphaltic oil on unformed and uncared-for country roads has often been tried and found to be useless, as noted on page 39.

OILED SAND ROAD IN MASSACHUSETTS.

Methods.—In 1905 and 1906 the Massachusetts Highway Commission oiled a common sand road in the town of Eastham (on Cape Cod, where there is no stone available), using a heavy Texas residual oil containing sixty-five per cent of asphalt. Two applications, each of three-quarters gallon per square yard, were made in 1905 and one in 1906. The oil was heated to 180° F., and was spread from a watering-cart with special sprinkler. Two weeks after the first coat, the second was applied, and the whole oiled surface was then thoroughly chopped up with a disc harrow, rolled with a light horse-drawn roller and then covered with sand. Thin sprinklings of sand were added from time

to time to cover oil which came to the surface. The results were generally satisfactory and the road in 1908 was in good condition after two years of use. The total cost for the two years of treatment, exclusive of shaping, grading, drainage, and stone, etc., was twenty-two and one-fifth cents per square yard, or $2083 per mile of sixteen-feet roadway. The Commission believes that oil can be used to advantage on a road of this kind where the roadbed is of loose sand, the drainage good, the traffic light, and the cost of more permanent materials is high. Frost appears to have had no ill effect upon it.

SURFACE TREATMENTS.

"*Asphaltoilene*" is the trade name of a prepared residuum of Kentucky asphaltic oil, being a black, heavy oil which looks like tar, and consists of sixty per cent to sixty-five per cent of pure asphalt dissolved in and carried by enough petroleum to make it fluid, thus serving as a vehicle to deposit the contained asphalt upon the road-surface where the petroleum is absorbed or evaprates.

Method and Cost.—It has probably been more used in the Middle and Eastern States than any other one form of residual asphaltic oil, and gives good results when properly applied, in warm weather, to the dry surface of clean, hard, well-drained, well-crowned, crushed-stone roads. There is no expense for sand or screenings to be spread over it. Asphaltoilene is prepared and used by the Road Improvement Company of Cincinnati, Ohio, which company contracts for the completed surface at varying prices, averaging about four cents to six cents per square yard. It is applied hot from a

"White" machine, which distributes it by gravity evenly and in regulated quantity, forming a finished surface which is elastic, pliable, smooth, and waterproof, and it is claimed that this surface is maintained under heavy traffic by two applications the first year and one each succeeding year.

Extent of Use.—During 1906 and 1907, there have been thus treated roads in and near various cities, among them, Louisville, Kentucky; Cincinnati, Ohio; Detroit, Michigan; and Newton, Massachusetts. In Detroit, the West End Boulevard was coated with asphaltoilene in July, 1906, and has since served as the testing speedway for ten motor-car factories, as well as for pleasure. It is said that over 500 motor-cars travel it every day, and at high speed, and that its surface is dustless and good.

At Newton, Mass.—Asphaltoilene was applied to macadam roads in Newton, Mass., in 1907, under direction of Charles W. Ross, highway commissioner, who considered the results very satisfactory. The heating was necessarily done by steam and not by direct heat. When spread by a "White" machine on the road, it looked like tar, and required several days to soak into the road. It then was perfectly smooth and hard and had the appearance of black india rubber. If the road is well swept and thoroughly rolled to a smooth, hard surface before application, the results are good. The cost in Newton was six cents per square yard.

"Asphaltoilene" seems to closely resemble the heavily asphaltic oils of California, and to accord with the suggestion on page 52.

"*Asphaltine*" is another preparation of asphaltic residuum, which is made in Geneva, Switzerland, where

it is used on macadam roads in the vicinity with good effect. It is a mixture of the asphaltic residuum from the petroleum of Galicia, Austria, with mazout, which is a French by-product of petroleum refining. The mixture is used hot or cold, but the former gives the best results. The average cost in Geneva is about three cents per square yard, including labor of heating and spreading.

OILS DERIVED FROM GAS MANUFACTURE.

Summary.—"*Oil-tar*," "*tar-oil*," "*oil-gas-tar*," "*water-gas-tar*," are several names for a substance much used on English roads (and known as "*odocreol*" in France and Italy), which is a by-product of the manufacture of carburetted water-gas (used to enrich coal-gas) from the asphaltic residuum of Russian petroleum, known as "*solar-oil*," or other similar residuums.

"*Creosote-oil*" is a distillate from the coal-tar which is condensed during distillation of coal-gas from bituminous coal.

COMPOSITION.

Substances known commercially by each of these names vary as widely in composition and character as do the materials from which they are derived, and especially as the treatments of these materials vary. It is sometimes difficult because of these variations to account for success or failure in their use on roads.

"*Oil-gas-tar*," one of its several names, is a brown-black liquid having the odor and appearance of coal-tar, except that its greater fluidity permits its distribu-

tion from a sprinkler, without heating. Its specific gravity is about 1.04. Its composition is about as follows (see table on page 86):

Light	oils, volatile from	70° F.	to	170° F.	.....	11.2	per cent
Medium	" "	"	"	230 "	.....	22	"
Heavy oils,	" "	230 "	"	260 "	.....	16	"
Anthracene,	" above	260 "	"	...	.....	42	"
Water, 3 per cent; loss, 5.8 per cent;						8.8	"
						100.0	"

METHODS.

It may be applied cold, as it is exceptionally penetrating and abates dust well, but it requires several coats to give results. It is most effective when applied hot; in either case the road-surface must be thoroughly cleaned and put in good condition. It has usually been applied from hand-sprinklers, repeating the coating until the surface is filled. The protective asphaltic skin which quickly forms, prevents dust and is not much affected by light traffic which need not be interrupted during application, nor by rain which may come soon after it has soaked into the road, which it does quickly. But it does not endure heavy traffic and it does not resist heavy rains. Its advantages over coal-tar are that it can be applied more quickly, without interruption of traffic, and at less cost, which has been about one cent for the first coat and less for following coats, of which two or more may be required to constitute one application. Its duration is not great under traffic, and it can only be considered as being one of the best of the dust palliatives, and it has been extensively so used both in England and in France.

CREOSOTE-OIL.

"*Creosote-oil*" distilled from coal-tar, resembles coal-tar somewhat in appearance and has a characteristic objectionable odor. Mixed with resin, and mixed with tallow, and also alone, it was used on Liverpool roads in competitive tests in 1902 and 1903, and was then considered to give better results than any others of a number of dust preventatives which were tried (page 43). One-eighth gallon per square yard was applied with hand-watering cans and with syringes. Time was required for its absorption, and therefore one-half of the width of the road was treated at a time, so that rubber-tired vehicles could meantime use the other half. The conclusion of the tests was that creosote-oil was cheapest and most enduring. The dust was laid by it, and there was marked reduction in the wear of the macadam road-surface as shown by the reduced sweepings.

CONCLUSION.

Further experience has shown the greater durability and efficiency of refined coal-tar in preference to this derivative.

COAL-TAR PREPARATIONS.

SUMMARY.

Refined coal-tar, produced in gas manufacture and treated to remove its injurious parts and yet to preserve its ductility and to secure uniformity, has been generally accepted by the road authorities of France and England, and also by those road-engineers in the United States who have given the subject most attention, as being the material with which to improve broken-stone roads; binding the surface of existing roads and bettering the construction of new roads, thereby preventing the formation of road dust.

HEATING.

In the several following descriptions of heated tar applications, the desirable degree of heat is mentioned in each case, but in actual practice it is most difficult to regulate this closely. Even when thermometers are put into the tar to test it, there is no means of knowing the temperature at the bottom of the kettle where it may vary quickly, especially when a wood fire is used for the heating. In many cases where road-tarring has failed, this is no doubt a result of thus overheating the tar.

Kettles.—In some of the 1906 experimental work of road-tarring in New York, the wheeled tar-kettles were of seventy-five gallons capacity each, and a continuous supply of hot tar was secured by keeping a barrel of tar, or tarvia, emptying into the kettle at about the same rate that the hot tar ran from it onto the road.

In the 1907 Massachusetts work at Westwood, Wayland, and Weston, the kettles used were of five-hundred gallons capacity each, giving better protection from over-heating. They had wood-burning grates covering the entire kettle bottom, and also arrangements to have two barrels, and sometimes three barrels of tar emptying into the kettle while the hot tar ran out; but this latter feature was not much used. For suggested improvements, see page 119.

Steam-coils.—In any case where direct fire is used to heat the tar, there is danger of overheating and of the consequent failure of the work. To avoid this steam-heated coils should be used when possible.

UNIFORMITY.

For success in such use of tar, its quality is most important (see page 71). If it is heated too much and "refined" too far, it becomes brittle and makes black dust. If not refined enough, the light oils and ammoniacal liquors will disintegrate it. A reliably uniform product is essential. This requirement is supplied by "tarvia" in the United States and by "Clare's patent tar compo" in England, and doubtless by others.

Good tar, properly applied, is the cheapest and best form of dust-preventer and road-saver, being more effective and durable than any other now known.

OPINIONS.

Massachusetts.—In accord with this is the statement of Division Engineer Franklin C. Pillsbury, of the Massachusetts Highway Commission, made to the November, 1907, meeting of the Massachusetts Highway Association that,—

"The Commission concludes that, for the present, tarviating (or treating with prepared coal-tar) is the best method now known for protecting the surface of macadam roads."

This decision was reached after a year of use and observation of results on Massachusetts roads.

England.—This also accords with the opinion, in August, 1907, of Thomas Aitken, M. Inst. C. E., a recognized English authority on road-construction and author of "Road-making and Maintenance," who says:

"There can be no doubt that the building-up of the road-stone coating with a matrix of refined tar, chips and dust as a binding medium, is the best possible method of solving the dust problem in a satisfactory and permanent manner." (This refers to the results of forcing a fine spray of coal-tar into the road-material, rather than spreading the tar over the surface and trusting to absorption.) See page 89.

France.—French road-engineers also express the same opinions in the *Annales des Ponts et Chausses* after four years of experience in tarring broken-stone roads under their charge. M. Heude, chief engineer of the department of the Seine and Marne, and M. Sigault, M. Girardeau, M. Arnaud, and M. Vahheur, city engineer of Paris, all substantially agree that tarring has been shown to be a practical means of preventing

dust in summer and mud in winter, and that the saving exceeds the cost, and that future new roads will be tarred. The general acceptance in France of these opinions is further evidenced by the announcement that "the use of coal-tar and its derivatives will be given special prominence in the programme" of the International Road Congress, organized by the French Minister of Public Works, to meet in Paris in October, 1908 (see page 16).

United States.—Logan Waller Page, Director of the United States Office of Public Roads at Washington, D. C., states on April 20, 1908, regarding an application of crude tar, in August, 1905, that the results after two and one-half years are still good on portions of the roads, and on the whole have been satisfactory, the roads so treated being still noticeable for the absence of mud and dust. This refers to work done by the office at Jackson, Tennessee, where an old macadam road (of non-absorbent novaculite crushed rock), on the main business street, was treated with crude coal-tar from Alabama coke, at the rate of forty-five one-hundredths gallon per square yard. The tar was heated to 160° to 190° F., and was applied through a flatted, one-inch nozzle, and spread with brooms, during hot, dry weather.

Other opinions are given in connection with following descriptions of actual works.

CONDITIONS.

Success depends upon—

The quality of the tar, which must be the best possible;

The state of the weather, which must be clear and warm;

The condition of the road-surface, which must be clean and dry;

The manner of application, which must be rapid and complete.

OBJECTIONS.

Too much tar on the surface will be worse than the former mud and dust, being sticky when warm and slimy when wet. These objections are avoided when the tar, either cold or hot, is forced in a fine spray into the minute voids and spaces between the stone fragments, by means of pneumatic pressure from a "tar-sprayer," by which the quantity and the distribution are made uniform, and small pools of tar are not left on the surface.

TAR-SPRAYING.

Such a tar-sprayer must work so rapidly that full advantage can be taken of warm, dry weather, during which to treat one-half of the width of several miles of road per day.

Four kinds of such machines are made and used in England and one or more in France, as described on pages 69 and 89.

The application of tar by forcing a fine spray into the body of the road is too recent to predict the endurance

of a broken-stone road so treated; but the most conservative opinion of road-builders experienced in this work is that such roads will last at least twice as long as formerly, and that meantime there will be a considerable annual saving in the decreased cleaning and repairing. At the least, this means less cost and less dust.

FAILURES.

There have been many failures in using tar on roads, both in original construction and in surface treatment, or "painting." Some have been caused by the poor quality of the tar as detailed on page 71. Some have resulted from careless methods, some from excessive traffic, and some from unexplained causes.

In New York.—One conspicuous piece of road which was treated with tarvia in 1906 was more or less a failure, because no attempt seemed to have been made to dry damp spots in shaded portions nor to put the road in proper condition before application.

In Massachusetts.—Another case is in the city of Springfield, Mass., where half a mile of macadam roadway, on a four and one-half per cent grade, was tarviated in 1906. It is stated by Arthur A. Adams, superintendent of streets, that the tar, which had apparently been properly applied, had entirely disappeared within a year, under heavy traffic.

There are no doubt other failures, but the general opinion of users is favorable. One disadvantage of tar-painting with crude tar, is that a road recently so treated sometimes has a coat of black, slimy mud, when frost and snow are succeeded by continuous rain; and such mud is difficult to remove.

COAL-TAR PREPARATIONS.

HISTORY.

The use of coal-tar in the original building of broken-stone roads is no new thing, it having been so used in Nottingham, England, in 1840, and more or less throughout England and France for thirty years or more; and also in the United States. But its application to the surface of an existing macadam road was first made in France at Sainte-Foy-la-Grande, near Bordeaux, unsuccessfully, in 1880; and next at Melbourne, Australia, in 1886, where the macadam was first put in good, firm condition, and refined coal-tar was then spread upon it, and was covered with screenings of crushed stone. The results were so good that the method has since been continued there.

It was next used for this purpose by M. Girardeau, of Fontenay-le-Comte, road commissioner of the department of the Vendee in France, in 1896, on the State road from Lucon to Pointe de l'Aiguille. The results led to other tests in various parts of the great national road system of France, and in 1898 it was discovered that by applying the tar hot, it then better penetrated the road (being thus made thin like water), and that it cemented the road dust between the fragments of stone, which thus were held in a plastic but firm matrix.

TAR-SPRAYING MACHINES.

The tar treatment of road surfaces was then adopted in England, and inventors there and in France devised various machines for increasing the speed and decreasing the cost of application, which were mainly accomplished by forcing the tar, either cold or hot, by pneumatic pressure through spraying-nozzles, giving rapid and

uniform flow and distribution without the need of hand-sweepers. Those machines which are able to spray tar which is cold, thereby avoid the considerable expense and trouble of heating it. The heat is so quickly lost that it is of little effect after the tar is spread.

TESTS.

A competitive trial of these machines was held by the English Roads Improvement Association, acting with the Motor Union and the Royal Automobile Club, May 22 to 27, 1907, at Reading, in Berkshire County, England, where there were present road-engineers and representatives of motor-car associations from all parts of Great Britain, as well as from France, Germany, Italy, and Egypt. Eight machines and thirteen materials were tested by actual use, though the roads and weather were not dry enough for best results. Six months later, when the results of the work were known, the judges awarded two prizes, and made mention, in the order named:

First:—"Aitkens Pneumatic Tar-sprayer," two sizes, hot or cold tar under pressure.

Second:—"Tarspra," three sizes, hot or cold tar under pressure.

Third:—"Johnston-Lassailly Patent Tar road-binder," hot tar by gravity, spread by automatic trailing brushes.

Fourth:—"Thwaite anti-road dust system," hot tar under pressure.

Fifth:—"Tarmaciser," steam traction-engine to clean road; heat and apply tar and cover and roll. Each of these is described on pages 89–97.

The three first named are each very effective, having done much good work in England or France, or both. It is said in London that their best features may yet be combined in one machine. None are yet used in the United States, where distribution is still made by slow gravity flow, usually requiring that the tar be heated and be spread by hand-brooms, at high cost for labor, and at a rate of progress about one-twentieth of that at which better work is done in Europe.

COAL-TAR QUALITY.

It has come to be recognized since 1905 that "coal-tar" is a very indefinite term, and that the products of different gas-works vary widely with the kinds of coal used and the methods of treatment, each of which is frequently changed, even at the same gas works. This knowledge has led to careful tests and analyses of different types of coal-tar to determine, if possible, why some succeeded and others failed in road work. This induced treatment by experts to remove objectionable components and those which would be soluble in rain-water, and to add desirable ones which might increase fluidity or add to the permanence of ductility and adhesiveness, which should be such that after boiling, the coal-tar may be drawn out in long threads. Many failures which had formerly occurred were explained by the former omission of such tests and absence of such qualities. It is recognized that most road engineers lack the time and equipment to analyze each lot of tar, or to interpret the results of such tests, which are at best costly and uncertain and are of little general utility with the present knowledge of the subject.

There can be no successful system of tarring road unless there is available a uniform standard and a reliable supply of refined tar. The lack of these in England accounts for many failures, and has so far prevented the universal use which would be expected from knowing of the many successes.

SPREADING TARVIA FROM A SLOTTED SPRINKLER (Pittsburg, Pa.).

VARIATIONS.

Every city has its gas-works,—often several of them,—each using various grades of coal, and frequently changing their methods of treatment to make gas. Even when these features are constant, the quality of crude tar from a given supply-tank will vary as the quantity in the tank varies, the tar drawn from the bottom of a full tank sometimes differing materially from that drawn when the same tank is nearly empty. The resulting crude coal-tars are there-

fore produced in great variety, so that road-construction which succeeds at one time may fail at another. Most failures have resulted from using poor tar.

UNIFORMITY.

The need for uniformity is met in the United States by a prepared refined coal-tar, widely known as "Tarvia," which has been used and commended by the United States Office of Public Roads at Washington, and by the Massachusetts Highway Commission (page 65), and by many city and road engieners throughout the United States and Canada, where one million square yards were tarviated during 1906 and three millions in 1907. It is supplied and guaranteed by the manufacturers, the Barrett Manufacturing Company, of 17 Battery Place, New York City. It is also used in England where it is specified for the "Gladwell" system (see page 112).

In Great Britain, a similar place seems to be filled by "Clare's Patent Tar Compo," of Stanhope Street, Liverpool, to which was awarded the first prize at the competitive tests described on page 70, at which there were entered twelve other preparations. The tests then were not conclusive as to the others, as the roads were not as dry as they should have been. But the judges were satisfied as to the good qualities of the one named, and the road treated with it showed best results after five months, due in great measure to its extreme fluidity, which gave considerable penetration even when applied cold as advised by its makers. It also had body enough to hold together the small dust-forming particles. The odor was unobjectionable. One-seventh

gallon per square yard was applied in two coats, costing for the material a little over one cent per square yard.

CONDITIONS.

The same conditions of season, climate, and road apply to both of these materials, except that in England and France the cost of application is less and the rapidity

PRELIMINARY SWEEPING IN PREPARATION FOR TARVIA (Jackson, Tenn.).

is greater, because of the improved pneumatic machines there used for spreading.

TARVIA.

Preparations.—A road to be treated with this, or with any tar, should be of well-built, firmly bonded broken-stone in fairly smooth condition. If it is newly

SPREADING BY HOSE FROM TANK. (Michigan Boulevard, Chicago).

THE FINAL ROLLING. (Pittsburg, Pa.).

built it should have been opened to traffic and thoroughly dried out before preparing to tar it. Then the surface should be swept or scraped until the fragments forming the wearing surface are exposed.

If it is an old road, such thorough cleaning is specially important in order to remove any caked screenings which may have been left on the surface to protect it, or any foreign matters which may be there. If not removed before the tarvia is spread, they will afterward dry out and become loose and break the tarviated surface.

HOT TARVIA TREATMENT.

When the firmly-bonded macadam is thoroughly cleaned and perfectly dry, close the road to all traffic, or if this is not possible, close half of its width. Select a warm, dry day in summer, heat the tarvia (designated as "tarvia A" and having specific gravity of 1.30) to 160° or 180° F., and evenly spread one-third to one-half gallon per square yard. To heat it, use kettles with furnace beneath, mounted on wheels, or a tank-wagon fitted with fire-box; or a tank containing steam-coils heated from a boiler; or, in some cases, the tarvia is brought hot in tanks from the factory (see pages 63 and 120).

Spreading.—To distribute it evenly over the road, if none of the tar-spraying machines described on page 62 are available, or if there is no specially arranged sprinkling-cart or "White" sprinkler, then the spreading can best be done with an open hose from a tank-wagon, or from the bottom of a wheeled kettle, or by hand with pails. In either case, allowing it to flow

onto the road and there having four men spreading the tarvia with street-sweeper's fibre brooms.

Covering.—Traffic should be shut off from the tarred surface for two hours or more, until the tarvia has been practically absorbed, when new stone screenings should be spread to take up any surplus of tar which may remain on the surface, and the top should then be finished by rolling. After a few days, the road should be swept to remove any loose particles not bonded.

Cost.—The grade of tarvia thus used is "heavy," having specific gravity of 1.30, and being known as "tarvia A." This may cost $500 to $700 per mile of sixteen-feet roadway, varying with the cost of screenings and with the freight-rate on tarvia.

COLD TARVIA TREATMENT.

This grade of tarvia is "lighter" than "A," having a specific gravity of 1.10, and it is designed for use at less cost (about half that of "A"), without heating, and also without need for covering with screenings.

Spreading.—Any unskilled workman can apply it with a hand-watering pot to a dry, hard, broken-stone roadway, after sweeping the surface clean with a common broom. This grade of tarvia was first used in September, 1907, on the Merrick road between Bellmore and Wantagh, and at Oyster Bay, and at Hyde Park, all on Long Island near New York. The resulting surfaces are shown in views on page 79, where the fragments of stone forming the mosaic-like surface can be plainly seen but are firmly held in a matrix of tar and dust. These roads are macadam which had been stripped of the protective layer of screenings by the

passage of many motor-cars at excessively high speed, so that the one and one-half inch fragments of stone were exposed; prompt treatment was needed to save it. The "B" tarvia was put, cold, into the tank of an ordinary watering-cart to which was fitted a special sprinkler, consisting of a one and one-half inch pipe, perforated with eight one-eighth inch holes distributed over each inch of length. The road-surface was first swept clean and was then sprinkled with one-third gallon per square yard, which was then allowed to spread and be absorbed. No brooms were used on the tarvia, which was at once covered with the sweepings from the adjoining roadside. Traffic was not interrupted during or after the application.

Results.—There were no objectionable features; it did not track, nor was it picked up by motor-car tires; it gradually cemented the binder in the road-surface to resemble asphalt, so that the road could be cleaned, and the binder dust was no longer sucked out by the rubber tires of passing motor-cars.

Cost.—One treatment is intended to prevent dust and to reduce wear for a year at an average cost of three cents per square yard, or $300 per mile of sixteen-feet roadway.

MASSACHUSETTS ROADS.

On the main roads radiating from Boston, macadam of the best character has been built and maintained by the Massachusetts Highway Commission, and has been subjected to exceptionally heavy and fast motor-car traffic, as well as to the traffic of many horse-drawn vehicles. Franklin C. Pillsbury, division engineer of

EAST MAIN STREET, OYSTER BAY, L. I., N. Y.

MERRICK ROAD, BETWEEN BELLMORE AND WANTAGH, L. I., N. Y.

the Commission, states that the motor-car traffic was so injurious during 1906 and 1907 that, if newly built, the roads would need resurfacing in two years, and that if not preserved by some new method little would be left of some of these macadam roads in 1908.

TARVIA ON PARK ROADS.

Roads maintained by the Massachusetts Metropolitan Park Commission are described by John R. Rablin, engineer of the Park Commission. Three and one-half miles of park roadways were tarviated in 1906, using hot tarvia "A," covered with screenings. After a year of use, including the severe winter of 1906–7, about half of this was re-treated during July and August, 1907. From about one-ninth of the whole, the surface layer of tar and screenings scaled off in pieces one-quarter inch thick when the frost came out in the spring of 1907, evidently as a direct result of an excess of screenings which was left on the road when the tarvia was applied and which prevented the tarvia from penetrating at the spots so covered. In general, the winter had no bad effect on the parts properly treated.

Cost.—The average cost of the 1906 treatment, using tarvia "A" hot, and including screenings, was about six and four-tenths cents per square yard, and the re-treatment in 1907 cost about the same. Meantime the roadways were free from mud and dust. During 1907 other park roadways in the same system, equivalent in all to ten miles of sixteen-feet road, were treated with tarvia "A" at costs ranging from five and eight-tenths cents to nine and three-tenths cents per

square yard, varying with the condition of the roads, necessitating more or less labor, the cost of which ranged from one cent to three cents per square yard. The cost of the tarvia varied with the quantity, from two and one-half cents to three and eight-tenths cents per square yard, depending also upon the road condition.

DEFECTS.

On some portions of these roads the tarvia and screenings gathered in bunches by a peculiar and unexplained action; this did not injure the effectiveness but was unsightly. This same bunching has been observed elsewhere and has not been traced to faults in the road-surface, which was in each case put in perfect order before beginning the tarvia treatment. The bunches gradually wear off and leave no break.

LYNN, MASS.

One of the most marked instances of the good results from tarviating a road has been at Lynn, Mass., where the Massachusetts Highway Commission built, in 1906, a mile of good macadam across the marshes, where it was fully exposed to sun and wind, and had as much high-speed motor-car traffic as any road in Massachusetts. As the result of these conditions the road had to be re-surfaced in one year after completion.

Removal of Crust.—One month later, in July, 1907, tarvia "A" was applied, after first removing a half-inch crust of screenings which had been wet with salt water and had become so hard that harrows and picks were

used to loosen it at considerable cost. Where small patches of this crust were inadvertently left, it was afterwards necessary to remove them also.

Methods.—The tarvia was brought, still hot, from the works in Lynn, where it was prepared; but it proved that the best surface was made where the coolest tarvia was used. The location made it necessary to permit travel during tarviating, and half of the width was therefore treated at a time, with the result that the lapping of the two coats shows at the center and is unsightly.

Cost and Results.—The average cost was about eight cents per square yard, including the covering of the tar with coarse, quarter-inch sand, which was found to be more effective than fine sand. As the result of tarviating this road, it was free from dust and showed practically no signs of wear from the passage of many high-speed motor-cars during the next four months of 1907.

WAYLAND, MASS.

New Surface.—At Wayland, Mass., in 1906, a new broken-stone surface was put upon parts of an old macadam road. It has usually been considered that a new surface should be used for at least a month before treatment with prepared tar; but in this, case the clean newly-rolled stone was at once tarviated without any preliminary spreading of the usual screenings and water. The results of the tarring were best on the newly surfaced parts. For the material to cover the tarvia, various grades of sand and of stone screenings were tried, and the best was found to be the one-

quarter inch, or "pea," stone from which all free dust had been removed.

NEWTON, MASS.

Charles W. Ross, widely known as one of the most experienced road-builders in the United States, formerly State Highway Commissioner of Massachusetts, who has built and maintains the model road system of the Newtons, used tarvia "A" in 1906 and 1907 on the fine macadam roadways in Newton, Mass., adjoining Boston, where the high-speed motor-car traffic is excessive and destructive, especially on Commonwealth Avenue, which extends from Boston through Newton.

Methods.—In July, 1906, where the motor-cars had completely taken off the binding material and had left the one-inch stones bare and beginning to ravel, he swept the surface as clean as possible with a street-sweeping machine, and then spread about one-half gallon of hot tarvia per square yard, covering it at once with a thin layer of one-quarter inch sand or fine, screened gravel (avoiding the dust of screenings) and then rolled it. This formed a tarviated surface which stood well through 1906, and improved during 1907, when more similar work was done on adjoining roads.

Cost.—The itemized cost of the work was:

Tarvia "A," at 8 cents per gallon	$3\frac{7}{10}$	ct. per	sq. yd.
Screening, or coarse sand	$\frac{7}{10}$	"	"
Labor, cleaning, spreading, etc.	$4\frac{3}{10}$	"	"
Teaming, hauling tarvia, sand, etc	$1\frac{8}{10}$	"	"
Rolling	$\frac{6}{10}$	"	"
Total	$11\frac{1}{10}$	"	"

On roadways having very heavy teaming, Mr. Ross has swept and spiked the surface, covered it with a layer of one-inch stone, rolled it smooth, applied one and one-half gallons of hot tarvia "A" per square yard, covered this with screened gravel and rolled again till hard. All this cost nineteen cents per square yard, but Mr. Ross believes that it will last four or five years, and that it is well worth the extra material used.

PENETRATION.

In all these applications of tarvia in the vicinity of Boston, the material was of grade "A," specific gravity about 1.30, and it was all heated to 170° to 180° F. or more, to facilitate spreading by brooms. The heating aids distribution, but has little or no effect upon penetration, which varies on these roads, which are exceptionally good, from one-half inch on very hard, smooth surface to three-quarters of an inch or more in some cases.

RHODE ISLAND ROADS.

In the State of Rhode Island during 1906 and 1907, the State Board of Public Roads tarviated several State roads, and among them was one in the town of *Tiverton, R. I.* The operations are described by Asst. Engr. Arthur W. Blanchard, Assoc. Prof. of Civ. Engineering in Brown University.

Methods.—The road was swept in the usual way with stiff brooms until the mosaic surface of the No. 2, or top course, was exposed, when hot tarvia "A" was poured upon it and spread by brushes, and a thin coat of fine sand was then spread over the tarvia.

Steep Grade.—The section thus treated was on a grade of seven and one-quarter per cent, and the action on this steep grade was specially noted. The tarviated surface proved effective in shedding the water into the gutters, preventing the road from being gullied, while, contrary to the experience of English engineers with steep gradients, there was no trouble or complaint as to slipping.

Results.—The road was subject to more than the average motor-car traffic, being part of the interstate trunk line leading to Newport; but the surface had not scaled nor worn down to the stone after a season of use, and it was free from dust. The cost was eight cents per square yard.

On other roads similarly treated the tarvia coating scaled off in spots and on the edges, but as a whole the work proved to be satisfactory.

UNITED STATES EXPERIMENTS.

The United States Office of Public Roads, Logan Waller Page, director, during 1907 conducted experimental work of surface treatments at Wayland, Mass., in co-operation with the Massachusetts Highway Commission. Crude coal-tar was used alone and in special preparations and in various combinations with water-gas tar, of each of which the composition was as follows (see also page 59):

TABLE.

SPECIFIC GRAVITY AND COMPOSITION OF TAR PRODUCTS.

Kind of tar.	Specific gravity.	Ammonical water.	Total light oils to 120° C. (or 338° F.).	Total dead oils, 170° C. to 270° C. (or to 518° F.).	Residue per cent by difference.
Water-gas tar.....	1.041	2.4%	21.6%[1]	52.0%[2]	24.0%[3]
Coal-tar.....	1.210	2.0%	17.3%[4]	26.0%[5]	54.8%[6]
Special tar preparation.	1.177	0.0%	12.8%[2]	47.6%[7]	39.6%[6]

1. Distillate mostly liquid.
2. Distillate all liquid.
3. Pitch very brittle.
4. Distillate mostly solid.
5. Distillate one-half solid.
6. Pitch hard and brittle.
7. Distillate one-third solid.

Methods.—The roads treated were mixed trap and granite macadam about ten years old, being parts of the main thoroughfare between New York and Boston, sixteen miles from the center of Boston, having heavy traffic of both motor-cars and teams, producing excessive dust. The applications were made during the month of August, 1907, only in dry and warm weather, and were surface treatments only. The general method was to sweep from the road all loose dust and detritus just before the application of the tar. This was applied hot or cold, as stated, from a hose connected to a wheeled kettle or tank-wagon, four laborers following with stiff, long-handled brooms to spread the tar and to work it into the surface. As the roads could not be closed to traffic, a light covering of gravel or screenings was applied at once, though better results would have been produced if the tar could have been allowed to lie for several hours before covering it. Finally, fine gravel or half-

inch clean trap screenings was spread as a covering material in sufficient quantity to take up all excess of tar and to produce an even surface, when the whole was rolled with a twelve-ton roller until firm and smooth. The costs varied from nine cents to thirteen cents per square yard, but these are stated to be high because of the small areas treated and the excessive repairs and renewals required in preparation.

Conclusions.—The general conclusion here seemed to be as elsewhere that coal-tar in some form was preferable to water-gas tar in any form, being more effective as a binder and more durable. The crude coal-tar showed very favorably in comparison with the more costly special preparation of coal-tar. This initial saving was somewhat offset by the fact that the crude coal-tar required heating to a temperature of at least 145° F., ranging up to 195° F., while the prepared coal-tars could be used cold. The slippery surface during frosty weather was an objection which was common to all the coal-tars.

The experiments led to the conclusion, as expressed by Director Page, that the surface treatments with tar as above described, are palliatives rather than preventives of dust, and that some more permanent method of using coal-tar is essential for satisfactory results (see page 116).

APPLIANCES.

Crude methods were used in all these operations, although the engineers in charge appreciated the desirability of the improved appliances used in France and in England for similar works (see pages 70 and 89).

Heating.—The Boston outfit consisted of two five-barrel heating kettles mounted on wheels, one pair of

horses to move them, twelve to fourteen laborers to sweep the surface and to spread and cover the tarvia, and teams to haul sand and screenings as needed. The Rhode Island outfits were similar. The hot tarvia was led from the bottom of each kettle through a pipe, valve, and hose, from the open end of which latter it flowed by gravity out upon the road-surface where hand-brooms were used to spread it. No attempts could be made to spray the tar, nor to force it into the road, nor to get uniformity and rapidity of flow by pneumatic pressure. Under these restricted conditions, 1200 feet of sixteen-feet roadway, or 2000 square yards of surface, was an average day's work, or less than one-twentieth of the rate of work of the best machines in England and France, where much better penetration is also secured.

THE "WHITE" MACHINE.

Spreading.—The "White" machine, made by Theodore F. White of Los Angeles, California, and generally used in forming the petrolithic roads of that region, has also been used on some of the New York and Massachusetts oiled roads. It is a patented attachment to the rear of an ordinary sprinkling-tank by which the gravity flow of the contents of the tank, usually heated crude asphaltic oil, is controlled and regulated in width of application varied from eighteen inches to six feet, by gauges and valves, so that two men with four horses treat half a mile of sixteen-feet road per day. This machine would seem to be well adapted to applying heated tarvia "A," or cold tarvia "B," or any thin tar preparation.

TAR-SPRAYING MACHINES.

AITKEN'S.

The best of the tar-spraying machines (page 70) is the "Aitkens' patent pneumatic tar-spraying apparatus," made by Thos. Aitken, M. Inst. C. E., Cupar, Fife, Scotland, by which coal-tar, cold, can be sprayed in varying quantities as desired, under sustained pneumatic pressure sufficient to cause penetration to depth of one to three inches into the hard surface of a used macadam road. It can be fitted on an ordinary watering-cart, using the tank to carry the supply of tar, and attaching to the cart-frame the compressed-air "receiver" and the pump, valves, sprayers, and devices, all actuated by power from the wheel-axle of the horse-drawn cart. A large sized machine is motor-driven.

Attached back of the tank is the "receiver," which is a steel cylinder into which is first forced air at 100 pounds to 150 pounds pressure per square inch by means of the same force pump which also draws the tar-supply from the tank. When this air pressure is reached, as shown by a gauge, the pump is connected to the tank, and the receiver is then half filled with tar, causing the pressure in the receiver to rise to 200 pounds to 250 pounds per square inch, when the machine is ready for operation, for which only two men are required. The

used to loosen it at considerable cost. Where small patches of this crust were inadvertently left, it was afterwards necessary to remove them also.

Methods.—The tarvia was brought, still hot, from the works in Lynn, where it was prepared; but it proved that the best surface was made where the coolest tarvia was used. The location made it necessary to permit travel during tarviating, and half of the width was therefore treated at a time, with the result that the lapping of the two coats shows at the center and is unsightly.

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Teaming, hauling tarvia, sand, etc	$1\frac{8}{10}$	"	"
Rolling	$\frac{6}{10}$	"	"
Total	$11\frac{1}{10}$	"	"

a two and one-third inches finished surface layer, of five and one-half cents per square yard, or $516 per mile of sixteen-feet roadway. The reduced cost of maintenance and of cleaning is expected to offset this greater cost of construction.

Result.—The macadam road thus built with good tar is dustless and is better and more permanent than the ordinary broken-stone roads built with water, provided that care is taken, so far as possible, to consolidate the stones by rolling so that the fragments bond each other and do not depend upon the tar for support.*

SPRAYING SURFACE OF OLD MACADAM.

For tar-spraying the surface of an old broken-stone road, the surface must be clean and perfectly dry, taking special care to look for and to correct slight depressions in shaded parts of the road where moisture is likely to linger even when the rest of the road is perfectly dry. The tar-spray is applied to one-half of the width of the roadway, turning traffic onto the other half for twenty-four hours. This has been done to half of a sixteen-feet road, by an Aitken tar-sprayer, at the rate of two-thirds of a mile per hour.

Cost.—The cost of cleaning the road and spraying the tar (when a horse-drawn apparatus is used) has been about one-half cent per square yard for labor, or $47 per mile of sixteen-feet roadway. Using one-eighth gallon of tar per square yard with tar at five

* This feature is brought to its perfection in the graduated and adjusted sizes used in bitulithic or quarrite roads; but such accuracy in filling voids is not practicable in ordinary work.

cents per gallon, the total cost for one application, including labor as stated, would be one and one-eighth cents per square yard, or $111 per mile of sixteen-feet roadway. With the tar-sprayer attached to a motor-driven van carrying 800 gallons of tar, greater lengths of road can be treated per day, and the cost of spraying is proportionately less. This does not include the cost of dusting or sanding the surface to cover the fresh tar, but such sanding would usually be required in any case on any ordinary macadam road. Neither does it include any allowance for the probable loss, delay, and damage likely to be caused by rains which may come upon the tarring work while it is unfinished.

TARSPRA.

The "Tarspra," of No. 20 Victoria Street, London, S.W., is another patented tar-spraying machine which is used in a similar way and with about the same results as the one just described. The "Tarspra" is made in three sizes of 200 gallons, 700 gallons, or 1000 gallons capacity each, and these are horse-drawn or motor-driven. This apparatus takes the tar, either cold or hot, by means of a double-acting force pump fixed at one side of the tar-tank and actuated by chain-gear from the wheel-axle. This pump forces the tar to atomizing nozzles at the rear, where it is discharged in a fine spray and distributed in an even coating under pressure of 200 pounds per square inch, the jets being so disposed as to impinge upon each other in such way as to atomize the spray, giving two inches of penetration. Thirty or more of these machines of different sizes worked during 1907 in various parts of England, more particularly in

the County of Kent, tarring roads in some cases at the rate of a mile per hour. Various improvements suggested by practical experience will be embodied in future machines.

LASSAILLY-JOHNSTON.

The "Lassailly-Johnston Patent Tar Road-binder," after having been successfully used on the roads in France for several years, was introduced into England in 1906 in an improved form as a competitor with the two pneumatic machines just described. It distributes hot tar by gravity flow, depending upon automatic brushes and absorption, instead of forcing a fine spray as is done by the English machines. It is more complicated than they are, consisting of two vehicles, one in which to cook or heat the tar to 200° F. by means of steam-coils, and the other with which to distribute it. Into the heater the cold tar is drawn by a steam-created vacuum, and from the heater the hot tar is forced quickly into the main tank of the spreader, which is drawn by horses. From this main tank its flow into the regulating-tank is controlled by a float-valve which maintains a constant level, so that the gravity flow through nozzles is uniform onto the road, where four automatic weighted brushes spread it in an even and smooth layer, one laborer following with a hand-broom to insure complete spreading. The hot tar is said to penetrate one to three inches into the road-surface. It puts on a neavier coating than the spraying-machines and one which is more enduring, but the apparatus with its need for heating is more cumbersome and slow to handle. It has, however, done a vast

amount of good work both in France and England. One of these outfits has covered 2500 square yards (or over one-half mile of half the width of a sixteen-feet roadway) per hour, using on it five tons of boiling tar, thus doing the work better than was formerly done in France by fifty men.

Cost.—The cost, where tar is bought at five cents per gallon, is stated to be about six cents per square yard for two complete coatings, including a covering over the fresh tar of stone chips, trass, and dry Portland cement.

GOOD RESULTS.

The effect under ordinary conditions is to make the road free from mud and dust for a year.

In France.—The resultant annual saving in the reduced cost of sweeping, mud-scraping, and repairs, is stated by M. Heude, chief engineer of roads and bridges of the department of the Seine and Marne, to be one cent per square yard. The actual quantity of material swept from a piece of thus tarred macadam road near Paris being one-twelfth of the amount removed from the same road during a similar former period. The same engineer states that he tarred 24,000 square yards of macadam roads in 1903, 50,000 square yards in 1904, 150,000 square yards in 1905, with good results throughout, the cost in some cases being less than the savings, and that in future all newly-made roads and streets will be tarred.

In England.—In England during the five summer months of 1906, there were thus tarred by the Lassailly-Johnston machines about 120 miles of sixteen-feet roads,

including roads at Epsom, Shoreham, and Sutton, near London, and at Hove and Worthing, near Brighton.

THWAITE.

The "Thwaite Anti-road-dust" machine is a steel tank or boiler, fitted with a furnace-grate and a sprinkling apparatus. Tar and water are pumped into the boiler where the tar is heated to 300° F., and steam is also formed to give pressure for forcing the hot tar through fine perforations of the sprinkler onto the roadway. Meantime sprocket-gears from the wheel-axles operate two force pumps, one to force dehydrated tar into the boiler and the other to force air to add to the steam pressure. The result is that the hot tar is so atomized that the jets are nearly invisible until they touch the road-surface which they penetrate effectively, spreading tar over the surface in an enamel-like coating. The apparatus is horse-drawn or motor-driven, and is made in several sizes, the larger of which carries 300 gallons of tar. There is also an auxiliary tank, or tar-boiler with furnace-grate, to give continuity of operation. This system prefers that, in addition to the perfect dryness which is required by all tar applications, the road-surface shall be first heated with their hot roller to insure its being dry and hot, and that after tarring, the tar shall be covered with hot sand.

Cost.—The first cost of the comparatively simple apparatus is moderate, and less than the others. The work done is good and effective, but the cost of operation as described is evidently greater than that of either the Aitken, the Tarspra, or the Lassailly machines.

TARMACISER.

The "*Tarmaciser*" (of No. 7 Victoria Street, Westminster, London) is a 35 H.P. steam-traction engine to which are attached the various mechanical devices for simultaneously cleaning and loosening the road-surface, removing the dust, heating and distributing the tar, and spreading it with automatic brushes, after which the dust previously taken from the road is ejected over the fresh tar and is then rolled by the steam-heated wheels of the machine. It is most complete and complex, requiring skilled adjustment and management and does not seem adapted to general use.

CONCLUSIONS.

The number and the variety of these machines for rapidly applying tar are indications of the general recognition of the need for means to quickly treat great lengths of roads during the short periods when weather conditions are favorable, all authorities agreeing that tar should only be applied when both air and road are warm and dry (see "Conditions," page 67).

Their applicability to the original construction of new tarred roads (see page 90), when surface treatment of old roads is not needed, is an important economical feature.

TAR-MACADAM.

SUMMARY.

This name is applied to any crushed-stone, or crushed slag construction in which coal-tar, or a bituminous cement, or a material containing coal-tar or bitumen, or both, is used (instead of water) in binding the filler between the fragments of stone, or slag; the tar or bitumen remaining as a fixative to hold in place the stone chips, screenings, or sand forming the filler, "binder," or matrix for the fragments, thus aiming to better the road (as compared with ordinary, water-built macadam) by excluding water, reducing wear and preventing dust. The term is used in distinction from the surface treatment, or "tar-painting," described in the preceding pages.

Tar-macadam may consist of a tarred three-inch surface layer only, as described on pages 82, 105, and 107. Or more usually of tarring all the fragments in the entire road, either before spreading as described on pages 105 and 109, or after spreading in place on the road, as described on pages 107 and 118; or the "Gladwell" system, as describedon page 111; or the most perfect form in the bitulithic pavement, as described on page 127.

COMPARATIVE COST.

Any good form of the cheaper tar-macadams costs about one-third more than the ordinary water-built macadam of the same kind and depth of stone, because of the added cost of the tar or bituminous cement, and also because of the necessary restrictions as to working only in warm and dry weather, and also the need of repairing the injuries done by rain coming on incomplete work. But these initial increased costs are offset, when the construction succeeds, by longer life of the road and by less expense for cleaning, maintenance, and repairs.

RESULTS.

When good, a tar-macadam road is practically dustless and noiseless, offers little tractive resistance, and endures the passage of the rubber tires of high-speed motor-cars; and as it sheds water, it is not heaved nor disintegrated by frost. It has the disadvantage, in common with other pavements, of being slippery when frosty. Of the several modified forms, the cheapest successful one seems to be the "Gladwell" system, described on page 111.

HISTORY.

Tar-macadam roadways were first built on the London road at Nottingham, England, at a date variously stated as 1840 and 1845, and at Sheffield soon after. Other similar roads have since been built at many times and places in England and in France, and some in the United States since 1900. The earlier ones used crude coal-tar, mixed by hand with various kinds of stone,

and often produced failures because of the poor quality of the crude tar (see pages 68 and 71), or because of rain or cold during construction. Many of the old ones, however, are still in satisfactory use, as well as many new ones.

In recent years the necessity of having properly refined tar has become generally known (see page 71), and improved appliances for heating and hand-mixing the tar and stones have been used with much better results than formerly as to cost and character; the mixing has been effectively done in some cases with an ordinary concrete mixer.

In 1901 the Warren Brothers Company of Boston, Mass., proportioned, heated, and mixed the materials mechanically, as described on page 127; and in 1904, Brown and Clarke of Nottingham, England, produced a steam-operated machine which mechanically heats and mixes stones and tar, as described at page 102, preparatory to spreading it, cold, upon the roads. Tar-spraying machines, and tar-spreading machines adapted to tarring the stone in place, after it has been spread on the road, have been devised, and have been used, as described on page 71, in both England and in France for the surface tarring of roads, but these machines have not as yet been much used for making tar-macadam for which they are well suited, as described on page 65.

In 1901 there was originated in the United States, and since widely used, the bitulithic pavement, well known as being the highest grade of combination of broken stone and bituminous cement, which is described at page 127, with details of the 1907 type of portable outfit for building it.

METHODS.

Tar-macadam is more used in England than elsewhere, and the methods of construction there have been radically improved since 1905. In February, 1906, at a meeting of the Inst. of Civil Engineers, H. G. Whyatt, M. Inst. C. E., borough engineer of Grimsby, who had built tarred macadam roads during many years, described a new equipment which he had just finished at Grimsby (which was like one built at Sheffield in 1902 at a cost of $5000) for the purpose of better heating and tarring the broken stone, or blast-furnace slag, and which was described as being an improvement on former methods.

By Hand-labor.—It consists of cast-iron plates three-fourths inch thick and ten feet by twenty-four feet in area, supported on brick walls about three feet high forming flues, heated by five furnaces in which continuous coal fires are maintained. Crushed stone, or crushed slag, is spread over the hot plates in a layer six inches to ten inches thick, and turned two or three times, by hand, with shovels, until dry and hot, when it is wheeled to a mixing-board, ten feet by four feet, where three wheelbarrows full, or say half a cubic yard, is assembled and hot tar composition poured over it, turning meantime by hand-shovels until every fragment is covered with tar. It is then put on a wheelbarrow and tipped into a heap where it is left to "mature" for six to nine weeks. The tar composition for treating one ton of slag is formed by boiling together for one and one-quarter hours twelve gallons of crude coal-tar, two gallons of creosote-oil and fifty-six pounds

of pitch, stirring meanwhile. For crushed stone, the quantity is usually one-third less because of less absorption. Care must be used that the stones, or slag fragments, do not get hot enough to burn the tar and make it brittle. (A simple and effective rule is that the stones must not be too hot to hold in the hand.)

Five men thus treat twenty tons, or say sixteen cubic yards per day, the operation involving the hand-shoveling of the materials at least seven times, after which it must be stored as stated, before being again shoveled for transfer to the road for use.

Cost.—The cost at English prices of three cents per gallon for tar and creosote, $12.50 per ton for pitch, and $1 per day for labor, must have been at least $1.20 per ton or $1.44 per loose cubic yard; for the tarring of stone to form a finished thickness of six inches, this would cost thirty-six cents per square yard for the tarring only, which is excessive. At the prices in the United States this would be increased sixty per cent, making it fifty-eight cents per square yard, which is prohibitive.

By Machine.—In 1904 Brown and Clarke built and used at Nottingham, England, a machine weighing twelve tons and costing $1400, for heating, tarring, and mixing mechanically, with the work of two men (including the engine-runner), thirty-five tons of crushed stone per day, using eight gallons of crude coal-tar and sixteen pounds of pitch per ton, which, at the same unit prices, cost for the tarring sixty-two cents per ton or seventy-four cents per loose cubic yard, equal to a cost for the tarring of stone to form a finished thickness of six inches, of eighteen cents per square yard at English prices, or twenty-nine cents at United States prices.

This improved equipment consists of a hopper into which the crushed stone is tipped and thence fed automatically into the longitudinal pockets of an inclined cylinder with a worm conveyer, the whole operated by a four-horse power engine. Underneath are two coke fires which heat the cylinders and their contents and dry the stone, and also heat two attached tar-tanks which are mounted on a saddle over the revolving cylinder, through which the stone passes slowly (meantime being thoroughly heated and dried), and then drops into the trough where it is automatically sprayed with a regulated amount of heated tar and is turned and mixed by the worm-conveyer, which moves the tarred stone to the upper end where it is ready to be stored for future use as desired. The quantity of tar sprayed upon the stone is adjusted to the speed of the machine, so that there is neither an excess nor a deficiency.

Cost.—As has been detailed, this Nottingham machine does the work of tarring at one-half the cost of the similar work done by the so-called improved equipments for hand-labor at Sheffield and Grimsby.

Another similar plant was equipped in 1906 near Gainsborough, England, by Parry & Sons, where blue lias limestone from their quarries is crushed and heated and treated with refined tar, with which tarred limestone a competitive section of 2300 square yards of tar-macadam was built in 1906 at a cost of forty-four cents per square yard, including all materials and labor complete. This was claimed to be "as good as the best tarmac."

TARMAC.

Tarmac is a trade name for blast-furnace slag, coated and filled while hot with heated, refined tar and tar-oils. It is manufactured and laid by the Tarmac Company of Ettingshall, Wolverhampton, near Birmingham, and is more or less made wherever blast-furnace slag is available, being shipped from the iron districts to all parts of England.

HISTORY.

It was first laid in 1898 at Newark, near Nottingham, and the success there led to use elsewhere. The slag is crushed and screened into three sizes, like crushed rock. It is dried as before described, on iron plates, or in rotary cylinders, or is taken directly from the blast-furnace while still hot, and each size is separately tarred, using twelve to fifteen gallons of prepared, refined tar per ton of hot slag.

The road at Newark, near Nottingham, just mentioned, was formerly maintained by an annual coating of crushed granite, until 1898, when it was covered with a three and one-half inch layer of the first "tarmac," which lasted without repairs until 1905, when it was resurfaced with one and one-fourth inches of tarmac. It is said to be free from mud and dust.

OBJECTIONS.

Slag, which is very porous and absorbs most tar, is structurally weak and crushes readily under traffic, so that there is much room for choice in selecting only

such slag as is best suited to the purpose, its irregularity making careful inspection necessary. Slag having much sulphur or lime must be avoided. In making shipments by rail during hot weather it is sometimes found that so much of the tar has oozed out of the slag and has settled in the bottom of the car-load that the whole needs to be re-heated and turned before spreading in place upon the road.

METHODS.

The treatment used to make tarmac at Grimsby in 1906 is described on page 101, and is more or less the standard method. In some cases the slag is taken directly from the blast-furnace while it still retains its original heat, saving the expense of drying it and thus producing "tarmac" in its best form. It is deemed best to store the tarred slag for some weeks or months, or until the tar is absorbed and has "toughened" as much as possible, and also until any excess of tar shall drain off. Tarmac seems to have been more used than any other material in making the so-called tar-macadam roads in England, being in use by the road authorities of seven counties from London to Birmingham and Sheffield, and also by the authorities of eighteen corporations and boroughs, of twenty-eight urban districts and six rural districts.

Tarmac Surface.—When an old macadam road is surfaced with tarmac, the usual method is to remove all loose fragments and irregularities and to make the top of the old road firm and with the regular crown, and upon this to spread the tarmac of one inch to one and one-half inch size, four inches deep when

loose, rolling this to a finished thickness of two and two-thirds to three inches, covering the completed surface with fine slag screenings or sand.

Tarmac Construction.—When the entire road is to be made of tarmac, as at Grimsby, it is laid in three layers, each separately rolled solid. For the bottom course, fragments of two and one-half inch gauge are spread four and one-half inches deep, loose, and rolled to three and one-half inches; over this is spread a two-inch loose layer of one-inch gauge, which is rolled to one inch; over this is spread a one-inch loose layer of three-eighths inch gauge, which is rolled to one-half inch, the whole making a finished thickness of five inches at the center and three inches at the sides. The completed surface is then covered with fine slag screenings, or fine sand, as in certain stages of weather it otherwise becomes very slippery. The whole work must be done in dry weather, and preferably in warm weather. The water-proof character of the road is such that the crown or camber may be half that required for ordinary macadam.

Comparative cost.—In comparative constructions in 1907 at Gainsborough (not far from Nottingham where tar-macadam originated) a "tarmac" road coating four inches thick when loose and two and two-thirds inches to three inches thick when solid, cost fifty cents per square yard, while tar-macadam of blue lias limestone of the same thickness cost forty-four cents per square yard, or fourteen per cent more for tarmac than for tar-macadam. At the same time and place, a coating of water-worked whinstone (i.e., ordinary macadam) of half this thickness cost twenty-two cents per square yard, or the same as the tarred limestone for the same total cubic quantity.

CRUSHED STONE TAR-MACADAM.

Tar-macadam roads in England when made of crushed stone are usually of limestone, or of granite, or of trap, basalt, or whinstone (three names for similar rock), the extent of use being in about the order named; a hard, tough rock which breaks with a rough fracture being preferred when other conditions are equal. Preference is sometimes expressed for a porous rock which can absorb the tar, but the evident weakness of such material makes it undesirable for road-work.

METHODS.

In cases where an old macadam roadway is to be surfaced with tarred stone, the old road is stripped to the desired grade and the low places made good. The tarred stone of two and one-quarter to two and one-half inches gauge is spread in a loose layer six inches deep and is rolled to four inches; this is covered with a two-inch loose layer of three-quarter inch to one-inch gauge tarred stone, rolled to fill the interstices; the whole when solid is covered with a light coat of slag-screenings or sand. A surface treatment of refined tar applied once in two or three years serves to keep such a tar-macadam road in good condition with ordinary traffic.

In some cases crushed stone without tar is spread and rolled dry, and is then grouted or flushed with boiling tar or bituminous mixture of tar, pitch and oil, as described; a covering of half-inch chippings or screenings of stone being added and rolled. This method chills the boiling tar or mixture on the surfaces of the cold stones, reducing its wearing qualities, and it also

usually deposits an excessive quantity of tar at the bottom of the mass of stone; in hot weather this excess works to the surface and makes trouble. Such construction is not desirable, and is so described on page 118.

COMPARATIVE COSTS OF TAR-MACADAM.

Local conditions vary so much that it is useless to compare costs at different places. Actual results at places where both the ordinary macadam and the tar-macadam have been used are instructive.

In the Ethington district, near Manchester, England, tar-macadam has been extensively used since 1894, and has there been found to cost twice as much as ordinary macadam and to last four times as long before needing renewal, meantime having little dust or mud.

In Northumberland, tar-macadam cost one-third more than ordinary macadam when crude means of hand-mixing were used to tar the stone. The general use of mechanical mixing, as described on page 102, is expected to reduce the cost of tarred roads to rates little greater than the cost of dust-and-water built or ordinary macadam. In 1894 and 1895 J. George-Powell, now engineer of the Godstone district, near London, built tar-macadam roads in Pocklington, East Yorkshire, near York, which roads were still in good condition ten years after. In 1905, being still interested in tar construction, Mr. Powell made a drive of 1200 miles through the nine counties north of London, and found many tar-macadam roads, some many years old, and some recently built, and all of them were noticeable for their comparative freedom from dust and mud. The workmen employed upon them gave replies indicating considerable decrease

in the cost of maintenance. His extended experience led him to conclude that tar-macadam roads can be made to last seven to eight years, with comparative freedom from dust or mud and at less final cost, as compared with three years' life for ordinary macadam roads, which always have either dust or mud.

Tar-macadam made at Sheffield (where the method has been used for the past forty years) with the base course of tarred limestone and the top course of tarred slag, is said by Charles Froggatt Wike, M. Inst. C. E., county engineer, whose charge includes fifteen miles of long used tar-macadam roads, to cost the same per square yard as does the ordinary macadam made of crushed granite; the cost of tarring the limestone and slag being offset by their less original cost as compared with that of granite, the final cost being fifty-four to sixty cents per square yard, exclusive of foundations. He states that a typical suburban road of tar-macadam, fairly flat and having considerable traffic, shows an average annual charge, including the initial cost distributed over fourteen years and maintenance, of eight cents per square yard per year. On another tar-macadam road with lighter traffic, the average annual charge, including initial cost distributed over the same term, and maintenance, has been five cents per square yard. Mr. Wike urges the importance of keeping tar-macadam roads in good order, and of tar-painting the surface every three or four years, or as soon as they get rough. Tar-macadam made at Nottingham, where all the materials are at hand, costs forty-two cents to forty-eight cents per square yard. Similar roadways made at Battersea in London, where all the materials must be brought from a distance, cost eighty-four cents to $1.08 per square yard

In the annual re-surfacing in June and July, 1905, of the sixty-four feet roadway on the Victoria Embankment in London, where the traffic is both fast and heavy, comparative one hundred feet sections of tarred granite, tarred limestone and tarred slag were laid, each of six inches finished thickness. Crude methods must have been used, as it took a month and a half to lay the total of 2100 square yards. The granite failed at once and the limestone in three months, and both were replaced by ordinary macadam of Guernsey granite in November of the same year. The tarred slag was somewhat better. The failure of the tarred granite was attributed to wet weather during construction. The limestone and the slag were laid in dry weather. The costs were $1.08 per square yard for the tarred limestone and the tarred slag, and $1.26 per square yard for the tarred granite.

In 1908 Arthur Brown, M. Inst. C. E., city engineer of Nottingham (where tar-macadam is best known), in a paper read before the Royal Sanitary Institute, stated the cost of new tar-macadam, including foundations, to be eighty-four cents per square yard, where ordinary macadam, including foundations, costs sixty cents to sixty-six cents per square yard. This tends to confirm the estimate made on page 99 and elsewhere, that tarring under average conditions increases the cost one-third. Mr. Brown describes tar-macadam as being noiseless and dustless, but as being conducive to side-slip in "greasy" weather. It has been said that tarred surfaces were unsafe on steep grades, but a ten per cent grade in Nottingham is used by heavily loaded drays passing down, aided by sanding when needed, which agrees with the experience at Tiverton, Rhode Island, as described on page 85.

GLADWELL SYSTEM.

The "Gladwell" system, mentioned on page 15, is a method of surfacing macadam roads, either old or new ones, with a tar-macadam top which gives some of the effects of tar-macadam, as described, and at a less cost which will probably lead to its general use.

SUMMARY.

It consists in imbedding a two-stone course of untarred clean, crushed stone (usually two-inch gauge) in and between two layers of tarviated, one-quarter inch gauge, dustless stone chips, which form a matrix which is worked, by judicious rolling, into the spaces between the stone fragments from below upward and from above downward, finally sealing the surface so as to be waterproof by hot tarvia "A" and granite chippings.

HISTORY.

The system was devised by Arthur Gladwell, who has charge of road construction and maintenance at Eton, near Windsor, England, and was first used by him on the road at Stoke Poges in July, 1906. It has since been successfully used on the roads along the Thames in that vicinity, and elsewhere in England. Its low cost and ease of construction, and especially the fact that most of the work may be done in ordinary weather, will no doubt lead to its extensive use in the United States.

METHOD.

The road to be surfaced must be made regular and firm, the usual crown or camber may be flattened if desired, and the surface of the foundation must be kept cleanly brushed as the work proceeds. For the bituminous binder or matrix, provide clean granite chippings, free from dust and passing a quarter-inch sieve, and thoroughly dried in a heater.

Tarring.—While still warm, but not hotter than 100° F., these chippings are mixed with tarvia "A," heated to 175° F., in the average proportion of fifteen gallons of tarvia per cubic yard of chippings, less tarvia being required in warm weather and more in cold weather. Crude tar cannot safely be used, and tarvia is specially advised by Mr. Gladwell. The warm chips and the hot tarvia are mixed gradually like concrete until they form a plastic mass, which is preferably used at once, but which may be kept forty-eight hours or longer, provided the hardened surface of the pile is separated and worked over with hot tarvia. (Evidently a rotary concrete mixer could be well utilized for making this mixture.)

Spreading.—This matrix is spread in a three-quarter inch layer upon the prepared foundation, forming the "sub-binder" over about six feet in length of the road, and for about half its width, covering about forty-six square yards of surface with one cubic yard of the tarred material. It should be spread evenly and lightly, and must on no account be trampled upon or consolidated in any way until it has been covered evenly with a two-stone course of two-inch to two and one-quarter inch clean,

dry, crushed stone, a loose cubic yard of two-inch gauge stone covering about fourteen square yards of surface. Use stone forks (not shovels) to spread the stone, so as to leave out all small pieces and flakes and dust. Bring this layer of stone to within six inches of the forward end of the "sub-binder" already laid, and then lay another three-foot length of "sub-binder," following with the two-stone coat, and always arranging so that the workmen do not trample upon the "sub-binder"; also, leave a loose edge of both courses at the center line of the road to insure a good joint when the other half is built the next day. When the whole width of road must be done at one operation, scarify the center or traffic track for say twelve feet width, and remove the loosened materials for use elsewhere. Sweep the scarified surface clean, and then spread the "sub-binder" and the two-stone coat, as before described.

Rolling.—The two-stone coat being ready on a section of twenty-five or thirty yards in length of the road, begin rolling at once, using a fairly light steam-roller moving at slowest speed in order to press the stones gently down into the matrix, and at the same time to draw the matrix upward between the fragments. This is not accomplished so well by a heavy roller as by a light one judiciously used. As soon as the "sub-binder" is seen to be working up between the stones, sprinkle some of the same bituminous material lightly over the top of the stones and carefully brush it into the surface voids until they are fairly well filled, the binding material or matrix thus working both upward and downward under the action of the roller until the new surface of the road is solid. Thus much of the construction may be done in any ordinary weather and need not be con-

fined to the warm and dry weather usually required for tarred construction.

Finishing.—For the completion or "surface sealing," warm, dry weather is essential. It is useless to attempt it during wet weather. One-sixth gallon of heated tarvia "A" per square yard of surface may be sprayed over the surface by one of the machines described on page 70, or it may be applied otherwise, the fresh surface being at once covered with a one-quarter inch layer of clean, dry, quarter-inch gauge granite or trap screenings, of which one cubic yard will cover 180 square yards of surface. The road should then be well rolled. If it is desirable to complete the surface sealing by hand as the work progresses, as is often the case, this may be done with hand-watering cans having V-shaped lip-outlets, spreading one-quarter to one-half gallon of heated tarvia per square yard and covering it, as before described.

This description provides for a finished, Gladwellized surface of two and three-quarter inches to three inches finished thickness. If a thicker coating is wanted, omit the "top-sealing" from the first course, apply another layer over it, and "top-seal" the last. If a thinner coat is wanted, as for roads having light traffic, reduce the size of the stones forming the "two-stone" layer, and reduce the thickness of the "sub-binder" proportionately.

Cost.—On the roads thus built by Mr. Gladwell at Slough and by George W. Manning at Staines, both near Windsor, England, the greater cost as compared with that of an ordinary macadam surface has been seven cents per square yard. The lesser thickness required reducing the quantity of stone and lowering the cost.

The inventor finds that with proper organization 450 square yards of surface, or 250 feet of a sixteen-feet road, can easily be completed in a day.

At prices in the United States the cost should not be more than the cost of dust-and-water built macadam plus twenty per cent.

Opinions.—The method is commended by H. Howard Humphreys, Assoc. M. Inst. C. E., in 1908, in a paper read before the Society of Road-traction Engineers in

SPREADING SCREENINGS OVER TARVIA (Jackson, Tenn.).

London. Practically a similar construction is proposed by Logan Waller Page, Director of the United States Office of Public Roads, as detailed on page 116.

TAR-MACADAM IN THE UNITED STATES AND CANADA.

SUMMARY.

There is as yet no general use of tar-macadam on rural roads, such work being so far done only on a small scale in an experimental way by the road departments of

some of the States, and by a few towns and villages. The use of the high-class bitulithic and its imitations has been confined to urban and suburban streets. The United States Office of Public Roads did some useful work at Jackson, Tennessee, in 1905, and the results as published by Director Page have been generally read and used as the basis for other experiments. The report says:

"A tarred street is dustless in the same sense that an asphalt street is dustless, though a fine sandy powder wears off as in the case of asphalt. In driving over a tarred macadam road, the lessening of vibration and noise is at once noticeable. The ordinary macadam produces a constant succession of slight jars upon a steel-tired wheel and there is a relief felt at once in driving upon a road treated with tar."

The United States Office of Public Roads continued to give special attention to the subject during 1906 and 1907, and in circular No. 89, issued April 20, 1908, Director Page expressed the opinion elsewhere quoted that surface treatments were palliatives rather than dust-preventives and that a more lasting method would be "the use of well-tarred sand as part of the binding material and to fill voids," applying a layer of such tarred sand to the rolled base-course, over which the top course should be spread and rolled until the tarred sand should work down into the base-course and up into the top-course. The surface being then finished by an application of tar covered with fine chips or sand and rolled until smooth and uniform. This suggested method is practically the same as the "Gladwell" system, described and commended on page 111.

In Canada, tar-macadam has been used to a considerable extent by the cities of Hamilton, Toronto, and

Ottawa. Hamilton (located midway between Buffalo and Toronto) built several miles of tar-macadam in the English method as early as 1880 and has maintained and extended it since to a total of nine miles of thirty-feet roadways in 1908 at initial costs of from seventy-nine cents to $1.06 per square yard. Toronto has built since 1902 about the equivalent of six miles of thirty-feet roadways costing about $1.50 per square yard. Ottawa, since 1902, has built about half as much, costing from $1.24 to $1.57 per square yard. The latter being particularly well built and successful in being clean and dustless, but being too costly for other than city streets.

METHODS.

In Rhode Island.—In 1906 and 1907 the State Board of Public Roads of Rhode Island used tar in constructing a macadam road on a main State highway, near Charlestown, in method described by Assistant Engineer Arthur W. Blanchard. The road is of special interest because it is part of a main trunk line between New York, Newport, Providence, and Boston, and is therefore subject to the maximum of high-speed motor-car travel. The macadam was built in much the usual way with the addition of tar. The bottom layer of one and one-quarter inch to two and one-half inch crushed stone, six inches loose and rolled dry to four inches, was sprinkled freely over the top with hot tar from dippers. Half-inch to one and one-quarter inch crushed stone was then mixed with hot tar by turning by hand-shovels and rakes on dumping-boards until all surfaces of stone were fully coated, when it was at once spread in a three-inch loose

layer and rolled to two inches finished thickness. A thin coating of screenings and dust was then spread and rolled upon the freshly tarred stone. The whole work was done only when perfectly dry, and was begun and completed each fair day at the rate of one hundred lineal feet, or 154 square yards per ten hours.

Cost.—Five extra men did the tarring at a cost for labor of six cents per square yard. One and one-seventh gallons of tar per square yard was used, costing ten cents per gallon, but this was partly offset by a saving of one and three-quarters cent per square yard from not using any water, making a total cost for the tarring of sixteen and one-quarter cents per square yard. The road thus built endured the severe winter of 1906-1907, and the traffic through 1907, without showing perceptible change and without dust.

On the Narragansett Pier road, in 1907, tarvia "A" was used in constructing a new tar-macadam road. The lower course of six inches, loose, of untarred crushed trap was rolled solid to four inches in the usual way but without water. and upon it was spread two and one-half inches to three inches of dry, untarred half-inch to one and one-half inch crushed trap, which was lightly rolled. The tarvia, which had been heated in tar-kettles, was then poured upon the surface of the lightly rolled top-course and was allowed to penetrate, going in one to two inches. Eight-tenths gallon to one and six-tenths gallons per square yard was used, varying according to the amount of rolling and the size of the stone. Trap screenings, half-inch to dust, was then spread over the tarred surface three-quarters of an inch deep, and the whole was then rolled until firm and smooth. The only

added cost was for the tarvia. Similar English work is described on page 107 as being undesirable.

In Massachusetts.—The comparative cost of tar-macadam and ordinary dust-and-water built macadam in Massachusetts is clearly discussed by Assistant Engineer H. C. Poore, in the 1908 report of the Massachusetts Highway Commission, estimating that a dust-and-water-built macadam of five inches finished thickness costs fifty-three and one-third cents per square yard, and that a similar tar-macadam road costs sixty-eight and one-half cents per square yard, equal to the cost of the ordinary macadam plus twenty-eight per cent. The tar-macadam estimated upon consists of an untarred base-course bound and filled with dry screenings or sand and rolled until firm and three inches thick. This to be covered with a two-inch finished thickness of tarred top-course of half-inch to two-inch stones (using a rotary concrete-mixer to coat the stones with two-thirds gallon of tar for one-ninth cubic yard of loose stone, or enough to make one square yard of top-course). This course after rolling to be covered by a top dressing of "pea" stone, or coarse screenings, treated after spreading and rolling with four-tenths gallon of tarvia "A" per square yard, which is also rolled. These estimates are based upon the assumptions that the subgrade is completed ready to receive the macadam; that the crushed stone costs $1.25 per ton (or about $1.50 per cubic yard), delivered; that tarvia delivered on car costs seven and one-half cents per gallon, and that the labor of tarring the surface costs two cents per square yard. This construction is expected to eliminate dust and prevent ravelling at a reasonable cost.

Kettles for Heating—Mr. Poore commended the use of 500-gallon kettles to heat the tar in preference to smaller ones (see page 87), and advised that the wheels of the kettles should be fitted with five-inch tires, and that there should be spigots at each end of the kettles so that all of the contents might be run out when on inclines, and that the hose should terminate in a funnel attachment to deliver the hot tar in a broad, thin stream.

ROCK-ASPHALT MACADAM.

SUMMARY.

This construction gives good results, but the cost of transportation has limited its use to the vicinities of the natural formations of the peculiar sandstones and limestones which are impregnated with bitumen and are known as "rock-asphalts."

The natural formations which occur in Arkansas, Indian Territory, and Kentucky, are sand-rock impregnated with a proportion of bitumen varying from a trace to a maximum of thirteen per cent, six per cent being about the least useful proportion.

The European supplies are those of France, Sicily, and Switzerland, and are bituminous limestones formed by natural combinations of about twelve per cent of bitumen with about eighty-eight per cent of amorphous carbonate of lime, and were first used for roads in Paris in 1854, and since then have made the comparatively small extents of asphalt pavements in European cities, being too costly for general use and much more slippery than the similar city pavements made from the American sand-rock asphalts, which are also costly.

METHODS.

For less costly roadways in the cities of the southwestern States of the United States, sand-rock asphalts from the formations in Arkansas and Kentucky have been combined with ordinary macadam in an effective way, which is described by Walter F. Reichardt, Assoc. M. Am. Soc. C. E., city engineer of Little Rock, Arkansas, in a paper read before the 1906 meeting of the American Society of Municipal Improvements. He has used the several kinds named and finds the Arkansas sand-rock asphalt to be the easiest to use, it being richer in bitumen and exceptionally good for rock-asphalt macadam. At Little Rock, Arkansas, the method is as follows:

CITY STREETS.

The subgrade is prepared in the manner usual for a good macadam road, using special care to remove all soft spots and to roll thoroughly.

Spreading.—The usual three-inch to four-inch base-course of one and one-half inch to two and one-half inch ordinary crushed stone is spread, filled with dry sand, and rolled without water. Over this is spread and rolled, dry, another three-inch finished thickness of the same sizes of crushed stone as the base, but without the sand filler. (The crushed stone used is trap, granite, limestone, or chert, whichever is most available.) Over this second course is spread a top layer sufficient to fully cover, formed of equal parts of ground sand-rock asphalt and half-inch to one-inch crushed stone.

Rolling.—This layer is rolled with a heavy steam-roller until firm and smooth; dry Portland cement is swept over the surface and the road is opened to traffic.

Results.—The pavement is not slippery, because the fragments of stone imbedded in the ground sand-rock asphalt give a good foothold. It needs care and must be kept clean.

Cost.—Its cost in Little Rock has been $1.40 per square yard, entirely preventing its use on other than city streets. A cheaper and more generally useful method is the following:

SUBURBAN ROADS.

In 1907 the United States Office of Public Roads, Logan Waller Page, director, made an experimental road at Bowling Green, Kentucky (as described in Cir. No. 89, of April 20, 1908), using Kentucky sand-rock asphalt, in which bitumen ranged in proportion from six per cent to eight per cent with a maximum of twelve per cent.

Kentucky Sand-rock Asphalt.—This is quarried like other rock and is crushed in the usual way into fragments to pass a two-inch ring, and the total product of the crusher is then taken to a series of roll-crushers which reduce it to a mass of separate grains of sand, each fully coated with a film of bitumen sufficient to cause the grains to adhere under pressure and giving the sand a rich, dark-brown color. (In this condition it costs $5 per ton f.o.b. cars at Bowling Green, Kentucky, one ton being equal to twenty-seven cubic feet loose measure.) If this sand is warmed in

the hand, the bitumen becomes soft and semi-fluid, so that the grains separate of their own weight, but when chilled (to about 60° F. or less) after compacting, it becomes hard and tough.

On an old roadbed reformed and crowned, crushed limestone of one inch to one and one-half inch size, was spread four inches deep and rolled once, dry, merely to turn down the sharp edges and to form an even surface. (This reduced the voids to probably about twenty-five per cent.)

Spreading.—The ground sand-rock asphalt above described, was then spread to a depth of one and one-half inches over this undisturbed surface, being thrown on with shovels from wagons or dumping-boards at one side of the road, one ton thus covering twenty-four and one-half square yards. Care was taken to break all lumps of the ground sand-rock asphalt and to work it into the interstices of the crushed stone.

Rolling.—Meantime the steam-roller was kept moving back and forth, working always parallel with the axis of the roadway and from the outer edge to the center; after the fourth or the fifth rolling, the sand-rock asphalt was forced into the voids and the surface became firm. The behavior of the ground sand-rock asphalt varied with the temperature, the bituminous sand working into hard, rounded lumps in the early morning when the temperature was about 65° F., and then spreading smoothly and compacting evenly as the temperature rose to 70° and 75° F. and upward. A light rain occurring at 65° F., impeded work, and portions which were then built did not compact and become hard for several hours after others built later.

Results.—The road when opened to traffic rutted badly under heavy loads at first, and was also seriously cut by hoofs. These bad features disappeared gradually after three or four days, and no trace of the ruts or the cuts remained at the end of a week, when the road looked like a sheet-asphalt pavement which had been sometime used. After four months it had undergone no appreciable change, and incisions into the surface showed no drying nor hardening of the bitumen, the sand particles moving as formerly when warmed in the hand. The pavement thus formed is dustless and the surface shows no appreciable wear.

Cost.—The total cost for material and labor (including shaping of subgrade and buying ground sand-rock asphalt and crushed stone) was forty-seven and two-third cents per square yard, or about the cost of similar thickness of ordinary dust-and water built macadam.

It is evident that this bituminous sand formed by crushing the twelve per cent sand-rock asphalt would be well suited to use in the Gladwell system, described on page 111.

Sheet Asphalt.—This bituminous sand produced by crushing and rolling Kentucky sand-rock asphalt has been used in the United States to make sheet-asphalt since 1890–1892 when ten miles on fifty-two streets were paved with it in Buffalo under five-year guarantees; the results were good, the repairs during eleven years averaging one cent per square yard per year. In San Francisco, Front Street was thus paved in 1890 and was in good condition without repairs after eleven years of heavy use.

Methods.—To form these pavements, the bituminous sand produced by grinding the rock is heated to 300

degrees F., and is spread hot directly upon the clean, dry, six-inch concrete base where it is rolled and rammed into a compressed layer two inches thick. No "flux" and no "binder-coat" is needed, the bituminous sand forming the entire surface. The cost was about the same as the more common artificial sheet-asphalt or $1.40 to $2.00 per square yard including the usual concrete base and the guarantee.

Binder for Macadam.—The success in this use indicates its availability as binder for macadam.

BITULITHIC PAVEMENT.

SUMMARY.

This is the best known combination of crushed stone and bituminous binder, and is composed of fragments of stone which are held firmly and free from attrition, and hence form no dust. It differs from other bituminous macadams in that the proportions of the several sizes of fragments of crushed stone, from two inches in size down to dust (which form about nine-tenths of the final mass), are accurately determined and are so combined in such proportions of the six or more sizes that the final voids between the fragments after rolling do not exceed ten per cent, or less than half the ordinary voids in rolled stone. This puts the fragments into actual and firm contact, so that the addition of ten to twelve per cent by weight (twelve to sixteen per cent by bulk) of bituminous compound fills the remaining voids and makes a solid and impervious mass. This result requires experienced care and skill in selecting and combining the best materials, including testing and analyzing the components of the bituminous cement. The pavement thus produced is one which water cannot penetrate, and it supports the passage of heavy and high-speed

vehicles without any loosening of the bituminous filler and without abrasion of the fragments of stone, so that no dust comes from the pavement or its materials.

OPINIONS.

With the present general knowledge of it which has been acquired since 1901, opinions are now of less moment than in its first years of use, when it was strongly commended by the writer and others who were quoted, in the 1902 edition of "City Roads and Pavements," and again in the 1906 edition, where it is described in detail. One of the best and most weighty of the opinions which have been published is that of George W. Tillson, president of the American Society of Municipal Improvements, Chief Engineer of the Bureau of Highways of the Borough of Manhattan (New York City proper), and author of the standard book, "Street Pavements and Paving Materials," who said before the Franklin Institute in 1906:

"Bitulithic pavement is made of crushed rock and bitumen, the particles of stone being mixed in certain scientifically predetermined proportions as to sizes, so as to provide a maximum of density and a minimum of voids, so that the resulting bituminous concrete is nearly as dense as a block of solid stone with a surface that offers as little resistance to traction as asphalt, but one that is not slippery, because the fine stone used in the finishing course provides a gritty surface, similar to macadam, which affords secure footing for horses at all seasons."

In November, 1907, at the meeting of the Massachusetts Highway Association (see page 13) to discuss "suppression of dust," Franklin C. Pillsbury, expressing the

opinion of the Massachusetts Highway Commission, of which he is division engineer, said:

"The bitulithic pavement is undoubtedly the best form of pavement to give the desired results (durability and freedom from dust under fast motor-car travel), but it is too expensive for many locations."

A practical expression of opinion was recently given by the Chicago South Park Commission, which selected it for use on several miles of fifty-feet boulevards after two weeks of investigation and after competitive bids for other forms of pavement.

HISTORY.

It was first used in 1901 in Pawtucket, R. I., where it was laid on a twelve per cent grade on Harvey Street. During the same year sample areas were built in seven cities, aggregating about one mile of thirty-feet width. The success was immediate, and the use increased each succeeding year, so that at the close of 1907 six and one-half million square yards, equal to 422 miles of thirty-feet roadways, had been laid in one hundred and sixty-six cities of the United States and Canada, including cities in the region of extreme cold, as at Edmonton, province of Alberta, Northwest Canada, and Glace Bay, Nova Scotia, and in the South at El Paso, Texas, and at Atlanta, Georgia. This wide-spread success has induced imitations and consequent litigations, which are further evidences, if such were needed, of the merits of the construction.

METHODS.

The base for bitulithic pavement is varied to best fit the local conditions. On gravelly soil which can be rolled solid, a bituminous base can be used, formed of crushed stone or slag of two inches to three inches size, spread to a uniform depth of four to six inches and

LAYING BITULITHIC PAVEMENT ON E. MAIN STREET, SPARTANBURG, S. C.
(See larger photograph of Flush-coat Spreading Machine and Stone-sprinkling Machine shown in background.)

rolled, dry, with heavy steam-rollers. This is followed by a coating or "binder" of hard, waterproof, bituminous cement. On soil which is sandy, or which cannot be rolled to be solid, an ordinary six-inch base of hydraulic-cement concrete is made, with the addition

of tamping into its plastic surface fragments of crushed stone in order to make it rough. On a formerly paved street, the old pavement can be used as a base for a bitulithic surface.

Upon the base of whichever sort, the "wearing surface" is spread and while still hot is compressed with heavy rollers to a finished thickness of two inches.

FLUSH COAT SPREADING MACHINE.
(Patented.)
Used in spreading the quick-drying bituminous flush coat on the surface of the bitulithic pavement.

STONE-SPRINKLING MACHINE
(Patented).
Used in sprinkling hot stone chips on the surface of the bitulithic pavement, to be rolled into the bituminous flush coat.

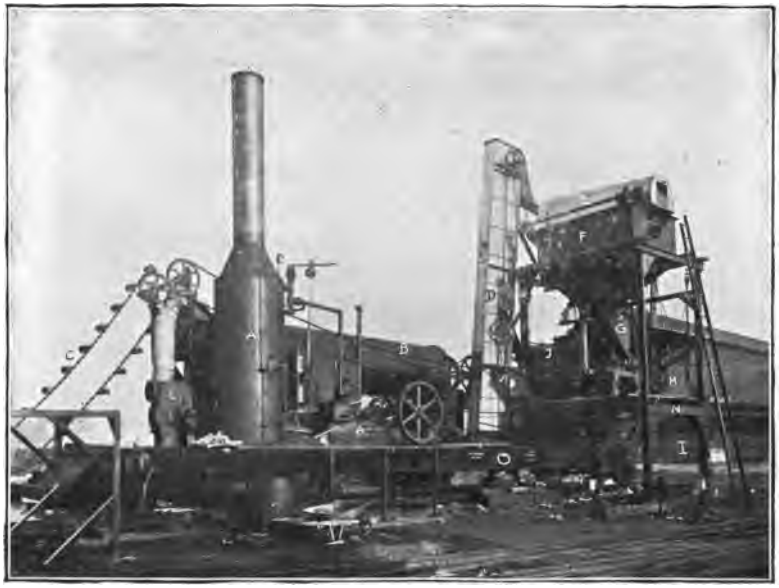
Proportions.—This wearing surface is formed of the best and toughest available crushed rock, varying in size from a maximum of one and one-half inches and one inch down to dust, which material is heated and dried in

rotary drums and is then screened in rotary screens, which separate it into six or more sizes. Tests are then made to determine the proper proportions of the different sizes which will produce the densest mixture having the smallest percentage of voids. These tests are daily repeated by the makers during the progress of the work upon samples taken from it, in order to have assurance of perfect uniformity in the pavement.

Mixing.—The determined proportions by weight of each size are run through the hopper of an automatic weighing-machine, into a mechanical mixer, at a temperature of 250° F., and are there combined with an accurately weighed proportion of heated bituminous cement, of which the composition is the result of close tests and which is carefully determined to be of a sufficient quantity (but not too much), to fill all final voids by coating the faces of all particles of stone and of sand and of dust, and also providing a slight surplus as a "filler."

Spreading and Rolling.—When thus mixed, the hot stone and bitumen is hauled to place on the road, and is there spread and rolled while hot, using a twelve-ton to twenty-ton steam-roller to assure the maximum compression which crowds the bitumen into all the voids and forces out all air-bubbles, and makes the most dense surface possible. Upon this surface, filling it and making it sticky, there is then poured and rubbed a coating of quick-drying bituminous cement heated to 250° F., over which is at once spread a quarter-inch layer of small stone chips which are rolled into the sticky coating and form a final wearing surface, the size of these chips being larger as the grade is steeper.

Dismantled ready for shipment.



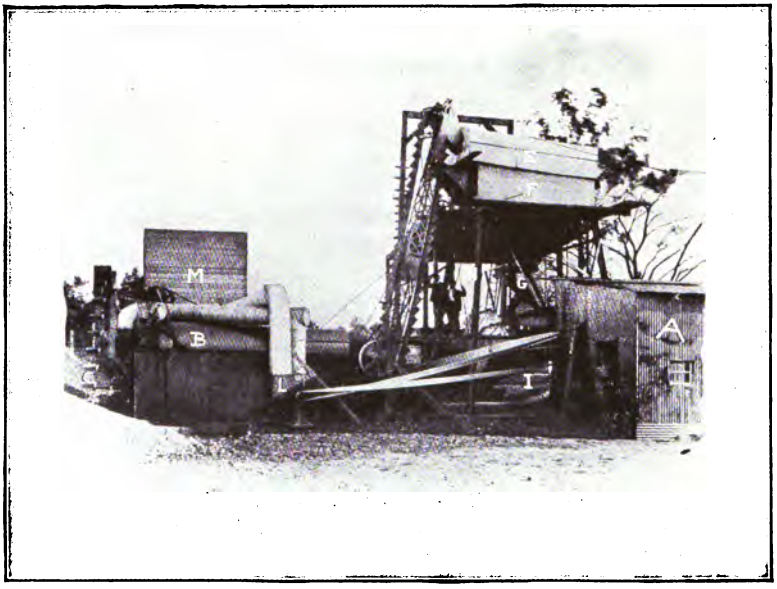
Set up ready for operation.

ONE-CAR PORTABLE BITULITHIC RAILROAD PLANT. (PATENTED).

The elaborate outfit of laboratory and machinery and skilled direction required to successfully produce this pavement would at first seem to limit construction to the vicinity of permanent plants, and this idea is strengthened by visiting such a plant and examining the work in progress. There have, however, been built and patented by the Warren Brothers Company, of Boston, Massachusetts, a number of "semi-portable bitulithic paving-plants," each permanently set upon a platform-car, of which full illustrations showing details are here given. These outfits make it possible to build this pavement in many widely distant places and to give to all of them equally reliable results. The six illustrations showing this "semi-portable bitulithic paving-plant (patented)" are all lettered to accord with the following key:

A. Boiler and engine.
B. Rotary driers for heating and drying stone.
C. Elevators for delivering the stone to the driers.
D. Elevators for conveying the heated stone to the separating-screens.
E. Sectional screen for separating the stone into several sizes.
F. Sectional bins for storing the several sizes of stone after separation, and delivering same to the weighing-box.
G. Weighing-box resting on a multiple seven-beam scale for accurately weighing each size of stone in predetermined proportions and delivering same into the mixer.
H. Twin pug mechanical mixer, having two shafts revolving in opposite directions with arms or blades interlocking each other.
I. Mixing platforms under which wagons back for taking the bitulithic mixture as delivered from the mixer.
J. Ogee-bottomed bitumen-melting tanks.
K. Bitumen weigh-bucket conveyor and dial-scale, so arranged as to indicate both gross weight and tare.
L. Rotary exhaust fan for providing induced draft to the rotary driers.

END VIEW.



SIDE VIEW.

SEMI-PORTABLE BITULITHIC PAVING PLANT. (PATENTED).

M. Dust-separator for reclaiming dust drawn by the exhaust fan from the stone while it is drying.

N. Steel frame for supporting the mixing-platform, mixer, scale, sectional hot-stone bin, and sectional screens.

O. Steel car on which the semi-portable or railroad plant is permanently set.

Cost.—The cost of bitulithic pavement varies with the local prices of the materials, and with the local conditions. It is usually $2 to $2.50 per square yard, exclusive of grading and inclusive of guaranty. This high cost limits its use to cities and parks, and prevents general use on rural roads.

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